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Source Category Survey
Secondary Zinc Smelting and Refining Industry

Midwest Research Inst.
Kansas City, MO

Prepared for

Environmental Protection Agency
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May 80

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16. ABSTRACT

This report describes the results of a survey of the secondary zinc smelting and refining industry to determine the probable impact of the development of new source performance standards under Section 111 of the Clean Air Act. This industry recovers zinc as metallic zinc, zinc dust, zinc oxide, or zinc alloys from scrap by melting or distillation processes. However, primary zinc smelters and refiners, who process zinc from ore, were excluded, even though they also process scrap to recover zinc. Information was gathered by collecting process, emission, and economic data from literature searches; contacting air pollution control agencies, other government agencies, industry representatives, and trade associations; and visiting a secondary zinc plant. The report describes the industry, projects production and capacity to 1989, and describes industry processes, actual and allowable air emissions, and emission control systems. State and local emission regulations are compared and the probable impact of a new source performance standard is assessed.

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PREFACE

This Source Category Survey Draft Report is submitted in partial fulfillment of EPA Contract No. 68-02-3059. The purpose of the report is to determine the need for New Source Performance Standards for air emissions for selected industries. The source category surveyed by this report is the Secondary Zinc Smelting and Refining Industry.

This study was performed by Midwest Research Institute for the Emissions Standards and Engineering Division of the U.S. Environmental Protection Agency at Research Triangle Park, North Carolina. The EPA lead engineer for this study was Mr. Reid Iversen. Principal Midwest Research Institute contributors to this study included: Dr. A. D. McElroy (Project Leader), Senior Advisor; Mr. Franklin Shobe, Associate Environmental Analyst; and Mr. Tim Arnold, Junior Analyst. This project was conducted in the Environmental and Materials Sciences Division under the supervision of Mr. A. R. Trenholm, Head, Environmental Control Section.

Midwest Research Institute expresses its appreciation to the industrial and governmental personnel who provided technical input and advice.

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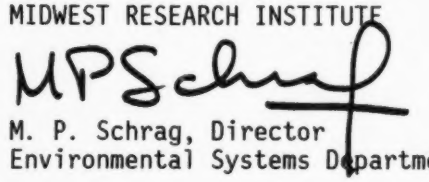

M. P. Schrag, Director
Environmental Systems Department

April 18, 1980

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1.0 SUMMARY

The secondary zinc industry is assigned a SIC number of 3341, secondary refining and smelting of nonferrous metals. In this study, the scope of operations included in the survey includes those plants which refine scrap zinc (and which may in addition process other scrap metals) via processes which range from zinc alloy manufacture in pot furnaces, through sweating operations to recover zinc in a relatively pure state (90 to 92 percent), to distillation processes which yield zinc metal as slab or dust, or zinc oxide as products. Most of the secondary commercial zinc is prepared by distillation, with alloying from scrap contributing a small percentage of the product output.

The annual production rate, on a zinc basis, in secondary zinc plants is about 50,000 Mg (55,000 tons). Production is distributed throughout most of the United States, with the exceptions of the Northern High Plains, the Intermountain States, and the Northwest. Ten plants presently produce distilled zinc products; two plants produce impure slab zinc from sweating operations; and four plants have been identified that produce alloys from a combination of virgin zinc and high quality scrap.

The secondary zinc industry has been typified over the past 20 years by numerous plant openings and closings and by intermittent operations. Within the last 5 years, one new plant has been placed in operation, and six plants have eliminated zinc from their product lines.

Growth in the overall zinc industry has been relatively low, about 2 to 3 percent per year, and forecasts indicate probable continuation of growth at low rates. Current secondary plants operate at 30 to 70 percent of design capacity, with 50 to 60 percent being a representative figure. The general economic picture for zinc is uncertain, due to several factors: pressure from imports; changes in the automotive industry which affect both the supply of recycle zinc and the market for zinc; current significant shifts in primary zinc production; and the impacts of increasing energy costs which tend to favor secondary zinc, but nevertheless, adversely affect the costs of producing zinc from scrap.

Current secondary zinc producers indicate no plans for expansion of operations in the foreseeable future, and in fact, most operate at significantly less than capacity. The potential for new sources is very small. Industry history indicates that idle capacity will be reactivated if the market picture for zinc improves.

Emissions from the secondary zinc industry consist principally of particulates plus nitrogen oxides generated by combustion of fuel, which almost exclusively is natural gas. Sweating operations release partially burned organic matter, but the principal particulate emission is zinc oxide plus small quantities of other metal oxides. Particulate emission factors range from negligible for pot furnaces or sweating operations with clean scrap to 20 to 30 kg/Mg (40 to 60 lb/ton) for distillation furnaces or dirty sweating operations. Total annual uncontrolled particulate emissions estimated for the industry are about 1,200 Mg/year (1,300 tons/year).

Emissions control systems predominantly consist of baghouses with an associated network of hoods and dampered ductwork. Two electrostatic precipitators were reported to be in use. The baghouse system is augmented with afterburners to help control particulates and to complete combustion of organics from sweating operations. Zinc oxide, the principal particulate, is controlled at 97 to 99 percent efficiency by these systems. Particulate control is practiced both to satisfy environmental regulations and to recover zinc oxide, a valuable product, which is sold for agricultural use or recycled into the zinc production business.

The particulate emission control systems, for an integrated plant with multiple furnaces of one type or another, are designed and operated on a scheduled basis for the separate sources. The effectiveness of overall particulate control is accordingly determined to a great extent by operator care (e.g., in opening and closing dampers). Given the necessary care to system operation, surveyed plants appear to have little difficulty meeting requirements of local or state regulatory agencies.

Controlled particulate emissions estimated for the entire secondary zinc industry are about 36 Mg/year (40 tons/year), at a control efficiency of 97 percent. Estimates for individual plants range from 11 to 16 Mg (12 to 18 tons) for the largest plant surveyed to 2 to 4 Mg (2 to 4 tons) for smaller plants. The emissions could be reduced to approximately one-third of these values by consistent operation at an efficiency of 99 percent.

State and local regulations for the secondary zinc industry are based heavily on visible emission limits. (A limit of no greater than 20 percent opacity except for 3 min/hr.) With this reliance on visible emissions, mass emissions data are very limited in quantity. The existing data are, however, consistent with uncontrolled emission factors used in this analysis. Controlled particulate concentrations less than 0.02 g/scm (0.01 gr/scf) (standard conditions are a temperature of 294°K (70°F) and an absolute pressure of 101 kPa (14.7 lb/in^2)) are supported by the data, as are controlled particulate emission rates of about 0.6 to 0.8 kg/Mg (1.2 to 1.6 lb/ton) of products. Current levels of control of particulates are significantly better than allowed by state regulations, by a factor of 5 to 10 because the particulates are collected for their economic value.

The impact of New Source Performance Standards on air quality will be essentially nil if projections of new capacity introductions are based on the uniform lack of plans for expansion or building new plants, and the amount of

idle capacity in presently operating and idle plants. However, if modest introductions of new capacity are assumed in response to a modest growth rate in secondary zinc production and to replace existing facilities, New Source Performance Standards would yield maximum estimated impacts of 19 Mg (21 tons) in 1984, and 39 Mg (43 tons) in 1989.

Development of New Source Performance Standards for the secondary zinc industry is not recommended. Justification for this recommendation is as follows:

1. No announced plans for additions to capacity for design changes or new plant construction were uncovered in the survey.

2. The potential for overall growth in production is small, being no more than 2 to 3 percent per year.

3. A majority of the plants presently in operation are operating at less than capacity, typically at 50 to 60 percent of capacity. Idle capacity would be considered for reactivation in the event that either local or national economics and demand improve.

4. The environmental impacts of a new source (with a probable production rate of 4,500 to 9,100 Mg (5,000 to 10,000 tons) annually) with state-of-the-art control are small. Emissions are only about 4 to 7 Mg (4 to 8 tons) of particulates annually.

2.0 INTRODUCTION

The authority to promulgate standards of performance for new sources is derived from Section 111 of the Clean Air Act. Under the Act, the Administrator of the U.S. Environmental Protection Agency is directed to establish standards relating to the emission of air pollutants and is accorded the following powers:

1. Identify those categories of stationary emission sources that contribute signficantly to air pollution, the emission of which could be reasonably anticipated to endanger the public health and welfare.

2. Distinguish among classes, types, and sizes within categories of new sources for the purpose of establishing such standards.

3. Establish standards of performance for stationary sources which reflect the degree of emission reduction achievable through application of the best system of continuous emission reduction, taking into consideration the cost, energy, and environmental impacts associated with such emission reduction.

The term "stationary source" means any building, structure, facility, or installation which emits or may emit any air pollutants. A source is considered new if its construction or modification is commenced after publication of the proposed regulations. Modifications subjecting an existing source to such standards are considered to be any physical change in the source or change in methods of operation which results in an increase in the amount of any air pollutant emitted.

The Clean Air Act amendments of 1977 require promulgation of the new source standards on a greatly accelerated schedule. As part of that schedule, a source category survey was performed to determine if development of New Source Performance Standards for the secondary zinc smelting and refining industry was justified and to identify what processes and pollutants, if any, should be subject to regulation.

Zinc-bearing wastes are processed by the primary zinc industry as well as by organizations which manufacture zinc product solely from scrap. This survey is concerned only with the latter group, i.e., those organizations which manufacture zinc, zinc oxide, and zinc alloys from scrap, and do not process zinc ores. The final products produced by these plants are generally the same as zinc from primary producers.

In typical processes, low grade scrap is sweated (melted away from major impurities), or distilled in furnaces using natural gas as fuel. The impure zinc from sweating operations is further refined by distillation in muffle furnaces or retorts. Distilled zinc is recovered as zinc dust or as slab or ingot, or may be oxidized directly to zinc oxide. Slab or ingot products are utilized in other plants, e.g., for the casting, galvanizing, or alloy production.

Emission sources primarily examined during this study were the exhausts from sweat furnaces, and the intermittent exhausts from pot furnaces or distillation furnaces. Emissions from pot furnace operations contribute a very small fraction of total emissions from the industry, however.

Information necessary for development of the secondary zinc smelting and refining source category survey was gathered through the following activities:

1. Collection of process and emission data from literature searches and contacts with State and local air pollution control agencies.

2. A visit to a secondary zinc plant to develop an understanding of smelting and refining processes, and to collect data on operating air pollution control equipment.

3. Contacting representatives of industry, trade associations, and government agencies to gather information on current secondary zinc smelting and refining production and projected industry expansion.

3.0 CONCLUSIONS AND RECOMMENDATIONS

3.1 CONCLUSIONS

1. In 1979-1980, 10 plants were identified which produce the following secondary zinc products: zinc slab or ingot, zinc dust, and zinc oxide. Two plants are engaged primarily in production of 90 to 92 percent zinc from scrap; this product must be further refined by primary or secondary zinc plants. In addition to these, several plants produce zinc alloys in pot furnace operations; these use some high grade scrap plus virgin zinc.

2. Annual production of the three products is about 50,000 Mg (55,000 tons). Of this, about 13,000 Mg (15,000 tons) is slab zinc, with the remainder being zinc dust and zinc oxide.

3. Six plants have discontinued production of secondary zinc products within the past 4 to 5 years. Generally, over the past 20 years, secondary zinc facilities have been operated on an in-and-out or intermittent basis. Production in existing plants is typically at about 50 to 60 percent of capacity, with the range being 30 to 70 percent.

4. None of the existing plants expressed plans for expansion of production either in new facilities or in present facilities. However, one new plant is coming into production in 1980.

5. Existing capacity is adequate for any growth which may occur. Possibilities for growth are clouded by downward trends in zinc usage by the automotive industry, which affect both the supply of scrap zinc and the market for zinc.

6. Air emissions consist of relatively large quantities of flue gas from natural gas combustion, and particulates from the refining and smelting operations. Particulate matter is principally zinc oxide.

7. Annual particulate emissions on an uncontrolled basis are approximately 1,200 Mg (1,300 tons). Controlled emissions are about 33 Mg (36 tons). Less optimistic emission factors yield controlled emissions of about 45 Mg/year (50 tons/year).

8. Available emissions estimates are based principally on engineering judgment, but are supported by limited plant emissions tests.

9. Current state regulations, while requiring tight adherence to standards for visible emissions, allow mass emission rates significantly higher

than actual rates. This level of control is a consequence of the fact that recovered particulates have significant economic value.

3.2 RECOMMENDATIONS

Development of New Source Performance Standards for the secondary zinc industry is not recommended. Factors that support this recommendation are:

1. One new plant with a capacity of 6,000 Mg/year (7,000 tons/year) could handle optimistic projections of possible growth for the next 5 years. Idle capacities in currently operating plants could, however, be used to conservatively increase production by 14,000 Mg/year (15,000 tons/year), and additional idle capacity exists in plants which have ceased zinc production, but are still active in related secondary metals.

2. No announced plans for additions to capacity, for design changes or new plant construction were uncovered in the survey.

3. Pollution control systems presently in use have the capability to adequately control emissions, given proper design and proper operation. Significant changes in basic design of pollution control systems for new sources does not therefore appear to be a requirement, nor are demonstrated economically viable alternates to present systems available.

4. The impact of New Source Performance Standards on air quality will be essentially nil if no new source production capacity is added, as indicated by the survey of the plants in the industry. More optimistic projections for the industry yield estimates of beneficial impacts of 19 Mg (21 tons) in 1984 and 39 Mg (43 tons) in 1989, assuming that emission levels equal to current state regulations are reduced to levels prescribed by the more stringent state regulations. However, current emission levels are lower than those allowed by the states, and a NSPS with an actual beneficial impact would have to be developed on tighter standards, i.e., on the basis of what can be achieved by current control technology. Based on the optimistic projection of new capacity addition, the maximum particulate emissions reduction is 3 to 4 Mg (3 to 4 tons) in 1984 and 6 to 8 Mg (7 to 9 tons) in 1989.

4.0 INDUSTRY DESCRIPTION

4.1 SOURCE CATEGORY

"Secondary zinc" denotes zinc derived from scrap, while primary zinc is derived from ore. The distinction is based solely on the source of the zinc. There is no difference in quality, and secondary zinc is made into the full range of zinc products.

Scrap is classified as old or new according to the stage of processing and use it reached. New scrap is generated during processing and is recycled without having been part of an end product. Old scrap is recovered from a product which has been used for some time.

Zinc scrap may be classified as metallic or residual. Metallic zinc scrap consists of zinc castings, which may be coated with another metal or with oil, or which may have such attachments as gaskets, electric insulation, or other metals. In addition to relatively pure zinc castings, there are many castings which are made from a zinc-containing alloy. The four types of alloys which are significant sources of secondary zinc are zinc-base, copper-base, aluminum-base, and magnesium-base alloys.

The residual scrap may be classified as skimmings or dross. Skimmings are primarily zinc oxide from surfaces of galvanizing baths and zinc alloy baths used for die casting. Skimmings contain metals and other compounds, in addition to zinc oxide. Dross is also formed in galvanizing and die casting. Dross is a molten metal which forms from chemical reactions and either floats to the top or sinks to the bottom. The molten metal has a high zinc content and typically includes some iron-aluminum compounds, copper and aluminum, or an iron-zinc compound. Skimmings and dross may contain some chloride flux.[1-4]

The recycling of zinc may be quite direct: prompt scrap, which is generated in metal fabrication or conversion processes, is often recycled within a given plant. Recycling may be slightly less direct, as is exemplified by arrangements between galvanizers and primary zinc producers in which galvanizing skimmings and dross are returned to the primary zinc producer as part of the basic sales agreement. Least direct is the recycling of old scrap, typically die castings. Old scrap can range in purity from the nearly pure zinc scrap from the engraving industry to scrap reclaimed from automobiles which is approximately 50 percent zinc when it is charged into the sweating furnace. New scrap from plants which use zinc alloys and highly pure old scrap are suitable for use directly in alloying, while less pure scrap requires processing before it is suitable for reentry into the zinc market.

Secondary zinc is made into the full range of zinc products. Figure 4-1 shows the principal products which were made from zinc scrap in 1972, a typical year for which detailed data are readily available. To give a perspective on the place of secondary zinc in the zinc industry, Figure 4-2 shows the supply and consumption of zinc in the United States in 1972. About 21 percent of the zinc supply was from scrap. This is a relatively low percentage for a nonferrous metal. More than half of the copper and lead supplies are from scrap. The low recovery rate for zinc, especially zinc from old scrap, results from the manner in which zinc is used--as an alloying agent, as a coating, or as a small object or fixture in a larger product. These applications make recycling difficult.[3,4]

Processing of the less pure grades of zinc scrap to commercial grade products involves some form of smelting and refining. A number of processes are available (see Section 4.3 for a description of processes). A common operation typical of the industry consists of "sweating" the scrap, a process in which the scrap is subjected to temperatures high enough to melt the zinc and effect a separation of impure (90 percent) zinc. Major impurities--aluminum, steel, copper--are recovered from the sweating operation and usually are themselves routed into their respective recycling industries. The still relatively impure zinc is then further refined by distillation processes. The distillation is effected in an oxygen-(or air-)free environment, insofar as possible, to prevent unwanted combustion of metallic, vaporized zinc to the oxide during the distillation. The distilled zinc vapor may be oxidized to zinc oxide by atmospheric combustion, condensed in small spherical particles (zinc dust), or condensed in the liquid state and cast into slabs (redistilled slab zinc).[2] With a given furnace, one may have the option of producing a single product (solid metal, dust, or oxide) or some combination of these products. Zinc oxide and zinc dust are common products from a single furnace.

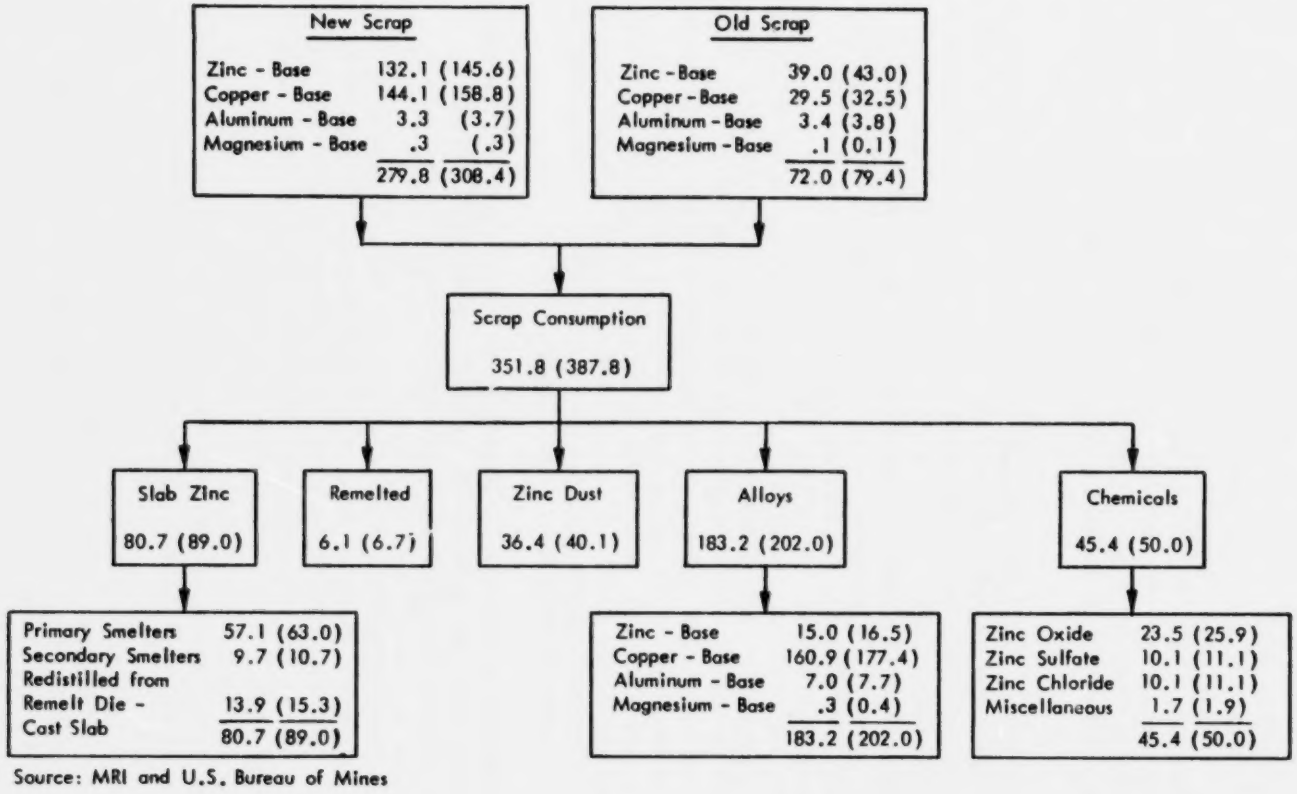
The sweating operation may be carried out in a plant as the only refining process, in which case the product is shipped to another secondary zinc plant, or to a primary plant, for further refinement.

The sweating operation may also be integral with a distillation operation, e.g., a muffle furnace, in which case the molten sweated zinc is fed directly into the muffle furnace. Alternatively, a given secondary zinc plant may cast sweated zinc in 454-kg (1,000-lb) sows, which in turn are melted down to provide a continuous feed for a distillation furnace.

With scrap of relatively high purity, the sweat process can be eliminated, and the scrap can be fed directly to retorts or muffle furnaces.

Sixteen plants in the secondary zinc smelting and refining industry have been identified. Companies presently engaged in smelting and refining of recycle zinc (excluding primary zinc operations) are listed in Table 4.1. Table 4.2 lists companies which recently eliminated recycle zinc from their operations. The significant features of these listings are as follows:

1. Two companies produce sweat zinc, principally from automobile scrap, and sell the product to other companies for further refinement.



Source: MRI and U.S. Bureau of Mines

Figure 4-1. Consumption of zinc scrap, 1972. (Gigagrams, zinc content)
(Thousand tons, zinc content)

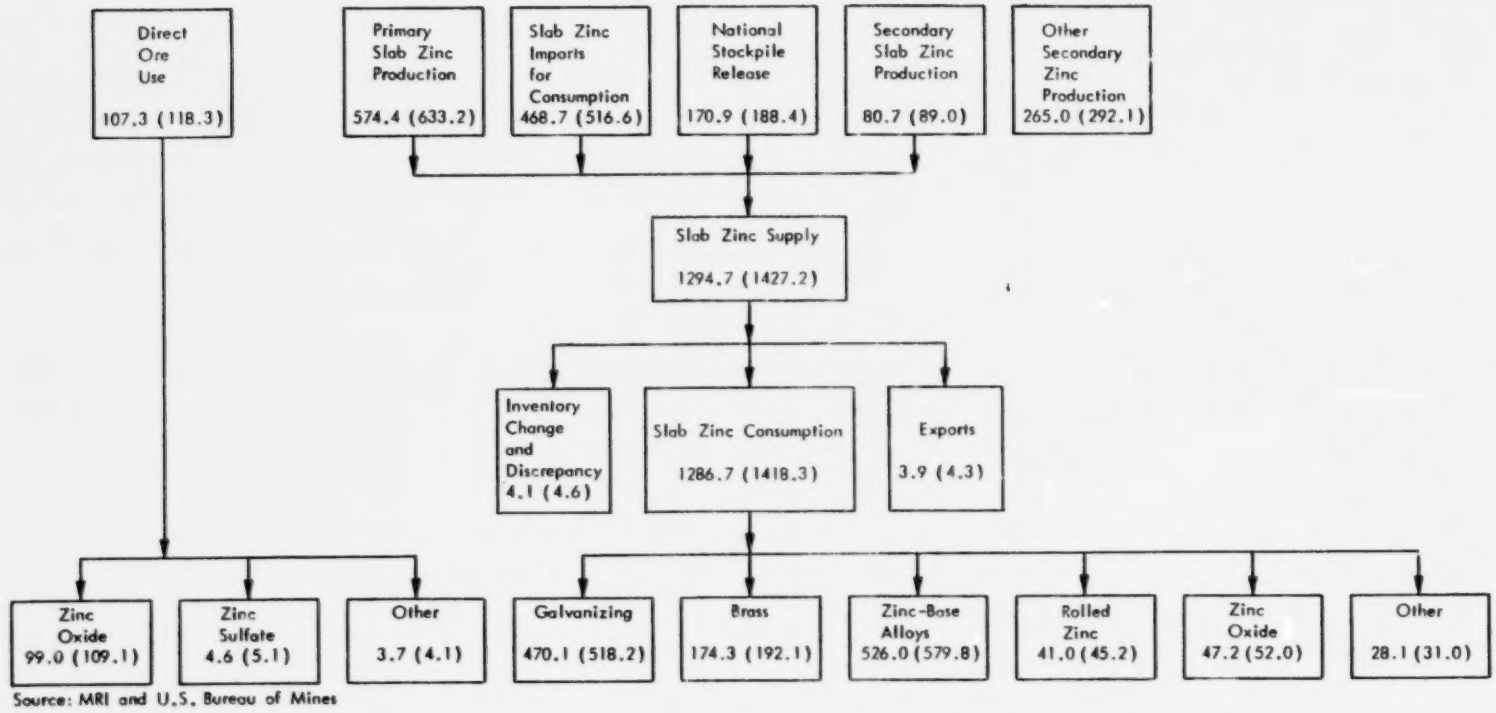


Figure 4-2. Zinc supply and consumption, 1972. (Gigagrams, zinc content)
(Thousand tons, zinc content)

TABLE 4-1. ACTIVE SECONDARY ZINC PLANTS

Company	Location	Processes	Raw materials	Products	Annual production capacity[b] Thousand MT	Annual production capacity[b] Thousand short tons	Operating rate[b] (percent of full capacity)	Number of employees[c]	Plant classification[d]
Pacific Smelting Company	Torrance, CA	4 Muffle furnaces 14 Distillaton retorts Rotary and sweat furnaces Kiln	Auto scrap Galvanizing dross General die casting scrap	Slab zinc Zinc dust Zinc oxide Zinc alloys	18.1	20.0	NA	168	R
Gulf Reduction Company	Houston, TX	9 Distillation retorts	Die casting scrap Galvanizing dross	Slab zinc Zinc dust	5.8	6.4	70	NA	R
W. J. Bullock, Inc.	Fairfield, AL	10 Distillation furnaces Ball mill	Auto scrap General die casting scrap Galvanizing dross	Slab zinc Zinc alloys	5.4	6.0	50	80-95	R
Federated Metals (ASARCO, Inc.)	Trenton, NJ	NA	Galvanizing dross	NA	NA	NA	< 100	NA	R
Federated Metals (ASARCO, Inc.)	Sand Springs, OK	14 Distillation retorts (horizontal) Melt-down furnace	Galvanizing dross Die casting scrap	Zinc dust	> 6.6	> 7.3	< 80	NA	R
Aetna Metals	Los Angeles, CA	Muffle furnace Rotary sweat furnace Stationary sweat furnace	General die casting scrap Auto scrap	Slab zinc Zinc oxide	NA	NA	NA	NA	R
Purity Zinc Metals (U.S., Inc.)[a]	Easton, PA	Retort distillation furnaces Proprietary process	Galvanizing dross and skimmings	NA	NA	NA	NA	NA	R
Canton Metal Alloys	Canton, OH	Rotary sweat furnace	Die casting scrap	NA	0.5	0.6	NA	5	R
Illinois Smelting and Refining Company	IL	Proprietary process	Die casting scrap Galvanizing dross	Zinc oxide	NA	NA	NA	NA	R
T. L. Diamond and Company, Inc.	WV	Retort distillation furnace	Galvanizing dross	Zinc dust	NA	NA	NA	NA	R
Huron Valley Steel Company	MI	Rotary kilns Induction furnaces	Auto scrap	Remelt	> 9.1	> 10.0	NA	40	S

(continued)

TABLE 4-1. (concluded)

Company	Location	Processes	Raw materials	Products	Annual production capacity[b] Thousand MT	Annual production capacity[b] Thousand short tons	Operating rate[b] (percent of full capacity)	Number of employees[c]	Plant classification[d]
Roth Brothers Smelting Corporation	Syracuse, NY	Rotary sweat furnace	Auto scrap General die castings	Remelt	4.5	5.0	30	125	S
Superior Zinc Company	Philadelphia, PA	Drying, calcining, refining	Zinc carbonate sludge	Zinc oxide	> 5.4	> 6.0	< 40	NA	C
Arco Alloys Corporation	Detroit, MI	Sweating (small)	Auto scrap General die casting scrap	Zinc-base alloys Brass	NA	NA	NA	65	A
New England Smelting Works, Inc.	West Springfield, MA	Pot furnace	Engraver's plates Roll zinc	Zinc-base alloys Bronze ingots	NA	NA	NA	30	A
S-G Metals Industries, Inc.	Kansas City, KS	4 Pot furnaces	High grade scrap	Zinc-base alloys Brass and bronze	2.7-3.6[e]	3.0-4.0[e]	30-35	300	A

[a] Scheduled to begin operating in early 1980.

[b] MRI estimates for all companies except Gulf Reduction Company, W. J. Bullock, Inc., and Roth Brothers Smelting Corporation.

[c] In multiproduct plants, employees may include those who do not process zinc.

[d] R = smelting and refining
S = sweating
C = calcining
A = alloying

[e] This is the zinc production capacity. About 5 to 10 percent of this is from scrap; the rest is from slab zinc.

TABLE 4-2. COMPANIES FORMERLY IN THE SECONDARY ZINC INDUSTRY

Company	Location	Raw materials
Apex	California	NA
Inland Zinc	Chicago, IL	Galvanizing
Imperial Metals and Chemicals	Chicago, IL	NA
Hugo Neu Proler Company	Terminal Island, CA	Auto scrap
Prolerized Schiabo Neu	Jersey City, NJ	Auto scrap
Rochester Smelting and Refining	Rochester, NY	NA

2. Three companies manufacture zinc alloys, utilizing virgin zinc plus a small percentage (5 to 20 percent) of high grade scrap.

3. Eleven companies produce distilled zinc, as slab, dust, or oxide, and may in addition operate sweat furnaces to provide feedstock for distillation furnaces.

4. Six companies have recently ceased secondary zinc operations.

This list is believed to be reasonably complete, but some smaller operators may not have been identified. On the basis of the survey, one concludes that 16 to 20 plants are operating now and that at least six plants ceased operations in the 1970's.

Zinc recycling is also a significant aspect of the primary zinc industry. The major primary zinc companies in the United States are New Jersey Zinc, St. Joseph Minerals, ASARCO, National Zinc, and Bunker Hill. The primary zinc companies generally accept zinc scrap, particularly from their customers (e.g., galvanizers), and feed the zinc scrap into their primary production processes.

The secondary zinc industry, as defined in this study, is responsible for only a small part of the supply of secondary zinc material, less than 30 percent of it in 1972. Most of the secondary zinc industry's production is included within the three product classes: slab zinc from secondary smelters,

9,700 Mg (10,700 tons); zinc dust, 36,400 Mg (40,100 tons); and zinc oxide, 23,500 Mg (25,900 tons) (Figure 4-1). Some zinc dust and zinc oxide are made from scrap by other processes. Zinc scrap is recovered in a variety of industries in a variety of ways.

More than half of the recovered zinc is in an alloy, typically a copper-base alloy. The zinc is usually not separated from the alloy. The alloy is recovered, remelted, and reused as an alloy, possibly with some addition of constituents to bring the composition to specifications.[1] Relatively pure zinc scrap may be remelted and reused in this way also.

Similarly, much of the zinc recovered from chemicals is recovered in chemical plants and reused in the form of a zinc-containing chemical.[2]

The reduction of zinc oxide from skimmings and other waste materials is for the most part performed in primary smelting plants in present practice.[1] Primary zinc smelters and refiners produce more than two-thirds of the redistilled slab zinc from scrap (Figure 4-1).

The limited production data from the listed secondary companies indicate that 3,500 to 5,500 Mg/year (4,000 to 6,000 tons/year) is an average production rate for intermediate size plants and that only two or three of the plants process more than the average (up to 14,000 to 23,000 Mg/year (15,000 to 25,000 tons/year)), with one of these producing remelt zinc (sows or slabs) which must be processed further by primary plants or other secondary plants. Production quantities (of secondary zinc) range downward to 50 to 100 Mg/year (55 to 110 tons/year) in some of the smaller plants. Total production for the secondary zinc plants (excluding secondary production by primary plants) is accordingly estimated to be 45,000 to 55,000 Mg/year (50,000 to 60,000 tons per year) without double counting and 65,000 to 75,000 Mg/year (70,000 to 80,000 tons/year) with double counting. The plants usually report that production is significantly less than capacity (30 to 70 percent). The average operating rate for the industry is estimated to be 50 to 60 percent.

4.2 INDUSTRY PRODUCTION

This section contains a description of secondary zinc sales and production and a description of the markets for secondary zinc products. The demand for secondary zinc is projected through 1989 and possible industry expansion is discussed.

4.2.1 Secondary Zinc Sales and Production

The U.S. zinc industry has suffered from uneven demand this century. Each war has reduced the zinc supply from foreign sources and significantly stimulated demand, especially for consumption in brass. In peacetime, the lower price for zinc will not support full use of the U.S. zinc capacity. Over time, the use of imports tends to increase.[1] The secondary zinc industry shares this shifting economic base and suffers also from the difficulty of recycling zinc, which is widely dispersed by use. A number of plants have come into service and left service as secondary zinc smelters and refiners in the last 20 years.

Only three plants which report slab zinc production to the Bureau of Mines have been in continuous service from 1957 to the present.[4]

The major products of secondary zinc smelters and refiners are redistilled slab zinc, zinc dust, and zinc oxide. All of these products are produced by other processes as well. The most detailed statistical information in a continuous series on the recovery of zinc from scrap is collected and published by the U.S. Bureau of Mines.[4,6] The Bureau of Mines data include production of redistilled slab zinc at secondary smelters and the production of zinc dust and zinc oxide from scrap. These data are shown for 1965 to 1979 in Figure 4-3. The 1979 results are MRI estimates based on preliminary data for the first 10 months of 1979.

4.2.2 Markets for Secondary Zinc Products

4.2.2.1 Redistilled Slab Zinc. The markets for redistilled slab zinc are the same as the markets for slab zinc produced from ore. Table 4-3 shows the 1978 consumption of slab zinc, which may be compared to the 1972 consumption in Figure 4-2.

The major markets are galvanizing, die casting, and brass and bronze.

The largest single use of zinc is for galvanizing steel to protect it from corrosion. A major use of galvanized steel is in building and construction, where it is used for roofing, siding, wiring channels, heating, cooling, and ventilation ducts, studs, joists, trusses, water pipes, fences (tubing and wire), guard rails, lamp posts, road signs, etc. Another major use is in the auto industry, where it protects the underparts of many cars. A third major use is in domestic appliances and office equipment. It is used for the casings of washers, refrigerators, etc., and for such steel office equipment as desks and filing cabinets.[7,9]

Approximately half of the zinc die castings are used by the automobile industry. The other major use is builders' hardware, which accounted for 21 percent in 1976.[10] The use of zinc die castings in automobiles has been decreasing. The zinc industry has met competition from aluminum and plastics by the introduction of thin wall zinc, which has about half the conventional zinc die casting wall thickness. Nearly all zinc die castings in the auto industry are thin wall zinc, which contributes to the auto industry's weight reduction program. The use of zinc in one 1966 model luxury car was 68 kg (150 lb) per car. Another full-sized 1966 model used 27 kg (60 lb).[11] The average use per car in 1966 was less than 27 kg (60 lb) because smaller cars used less than the models reported here. The trend toward smaller and lighter cars has reduced this to an estimated 14 kg (30 lb) per car average in the 1980 models.[12] The future for zinc in automobiles is uncertain. The Zinc Institute quotes "spokesmen for the automobile industry" as believing that the 1979 models are the turning point for zinc die casting and that growth lies ahead.[13] On the other hand, Chemical Week reported expected reductions to 9 kg (20 lb) per car in 1985 and 7 kg (15 lb) per car in 1990.[12]

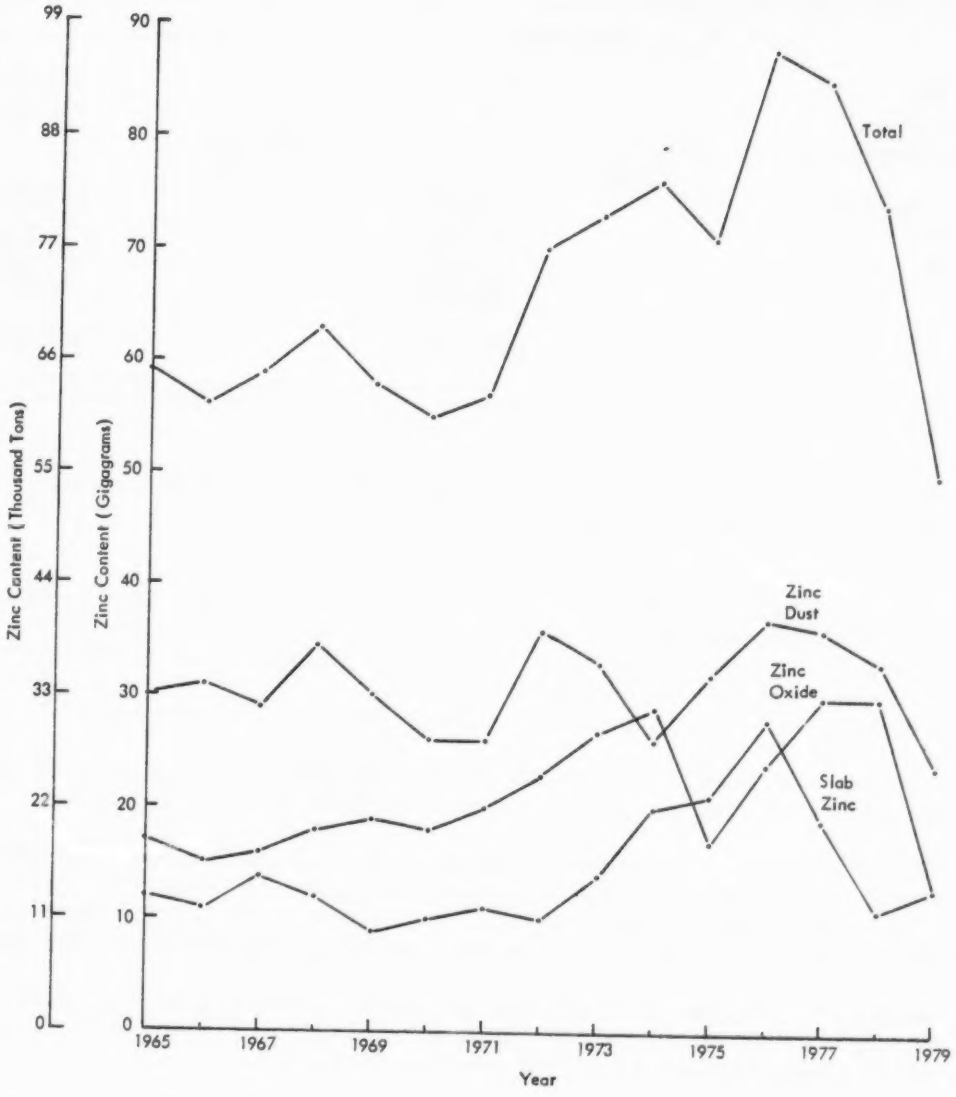


Figure 4-3. Secondary zinc production.

TABLE 4-3. CONSUMPTION OF SLAB ZINC, 1978

	Megagrams		Tons	
Galvanizing		454,014		500,465
Zinc-base alloy		354,134		390,366
Die casting alloy	345,968		381,364	
Other	8,166		9,002	
Brass and bronze		141,488		155,964
Rolled zinc		24,869		27,413
Zinc oxide		37,202		41,008
Other[a]		38,878		42,856
Total		1,050,585		1,158,072

Source: U.S. Bureau of Mines.[6]

[a] Includes slab zinc used for zinc dust, wet batteries, desilverizing lead, lightmetal alloys, and other miscellaneous uses.

The uses of brass and bronze are nearly too varied to be characterized. Important uses include hardware, plumbing, heat exchangers, automobile radiators (aluminum is competing for this), electrical components, and corrosion-resistant plates. The consumption of metal in brass mill products in the last 20 years has been cyclic with an annual growth trend of 0.9 percent.[14]

Redistilled slab zinc from secondary smelters accounted for only 10 percent of the 1978 slab zinc production (compare Figure 4-3 and Table 4-2).

4.2.2.2 Zinc Dust. The primary use of zinc dust is in zinc rich paints which are used both as primers and as complete protective systems on structural steel and as primers for the underparts of car bodies. It is also used as a reducing agent in the chemical industry and for bleaching wood pulp for paper.[5,9]

The secondary zinc smelters are the principal producers of zinc dust. In 1977, 36,000 Mg (40,000 tons) of zinc dust were produced (Figure 4-3) from scrap out of a total production of 43,177 Mg (47,594 tons).[15]

4.2.2.3 Zinc Oxide. The principal markets for zinc oxide are rubber, photocopy paper, and paints. Approximately half of the zinc oxide consumption is in rubber.[4,7,9] In 1978, as in 1972, 16 percent of the zinc oxide production in the United States was derived from scrap.[4,7]

4.2.3 Projected Demand for Secondary Zinc

The principal scrap sources for the secondary zinc industry are new residual scrap from galvanizing and die casting operations and old metallic scrap

(die castings) from automobiles and, to a lesser extent, appliances. The supply of suitable scrap limits the demand for zinc which can be met from secondary sources. Since zinc die castings are principally for automobiles and galvanizing is principally for construction and automobiles, the relationships since 1965 between secondary zinc production and, respectively, construction activity and automobile production were examined. There was no correlation ($r = -0.06$) with new construction, but there was a fairly strong correlation ($r = 0.85$) with the Federal Reserve Board Index for Motor Vehicles and Parts.

The demand for secondary zinc products follows much the same pattern as the scrap supply which was considered above, except that the rubber industry uses approximately half of the zinc oxide. However, there is also little correlation between secondary zinc production and tire production ($r = -0.11$).

A projection of secondary zinc production to 1989 was made by regression on time and on a rough index of the use of zinc in motor vehicles. The data base for the projection is shown in Table 4-4. An index of the use of zinc in motor vehicles was prepared by multiplying the Federal Reserve Board Index of Motor Vehicles and Parts by the estimated average weight of zinc per car as a percent of the present 13.6 kg (30 lb) per car. The index of motor vehicles and parts was assumed to grow according to the Predicasts composite forecast,[16] which is shown in Table 4-5. Since the forecast is published for 5-year intervals after 1980, the forecasts for the intervening years were made by linear interpolation. The projected index of motor vehicles and parts grows at an average annual rate of 2.2 percent from 1978 to 1989. The average weight of zinc per car was assumed to have remained at about 13.6 kg (30 lb) per car from 1965 to 1980 and to decrease linearly to 9.1 kb (20 lb) per car in 1985 and then decrease linearly to 6.8 kg (15 lb) per car in 1990.[12] The resulting index of the use of zinc in motor vehicles is also shown in Table 4-5.

The bilinear regression equation for the production of secondary zince is $Z = 36{,}904.1 + 1{,}519.345y + 163.028x$ where Z is secondary zinc production in metric tons, y is the year ($y = 0$ in 1965), and x is the index of the use of zinc in motor vehicles (1967 = 100). The value of r^2 is 0.736 which represents a moderately strong correlation for an economic model as simple as this one. The resulting projection is shown in Figure 4-4. It represents an average annual growth rate of 2.1 percent for 1978 to 1989.

The projections were based on the history of the secondary zinc industry from 1965 to 1978. If one covers the 1979 point in Figure 4-4, one can see that the projection is in line with the trend through 1978. The assumption underlying the projections is that 1979 is an anomaly resulting from temporary economic dislocations. If 1979 should prove typical of the next several years, the projections will have been too optimistic. The majority of the industry executives contacted in the telephone survey were pessimistic, although the opinion was not unanimous.

TABLE 4-4. DATA BASE FOR SECONDARY ZINC GROWTH PROJECTION

Year	Total secondary zinc tons		Federal Reserve Board Index of Motor Vehicles and Parts (1967=100)
	Tons	Mg	
1965	65,223	59,169	115.9
1966	62,014	56,258	113.9
1967	64,728	58,720	100.0
1968	69,414	62,971	120.3
1969	64,236	58,274	116.5
1970	60,757	55,118	92.3
1971	63,034	57,183	118.6
1972	76,704	69,585	135.8
1973	80,920	73,409	148.8
1974	83,372	75,634	128.2
1975	77,763	70,545	111.1
1976	97,471	88,424	142.0
1977	94,112	85,377	161.1
1978	81,076	73,551	170[a]

[a] Predicasts composite forecast.

TABLE 4-5. INDEX OF THE USE OF ZINC IN MOTOR VEHICLES

Year	Index of the use of zinc in motor vehicles	Index of Motor Vehicles and Parts (1967=100)
1965	116	115.9
1966	114	113.9
1967	100	100.0
1968	120	120.3
1969	116	116.5
1970	92	92.3
1971	119	118.6
1972	136	135.8
1973	149	148.8
1974	128	128.2
1975	111	111.1
1976	142	142.0
1977	161	161.1
1978	170	170
1979	162	162
1980	154	154
1981	152	163
1982	148	171
1983	144	180
1984	139	189
1985	131	197
1985	128	202
1987	124	207
1988	120	211
1989	115	216
1990	111	221

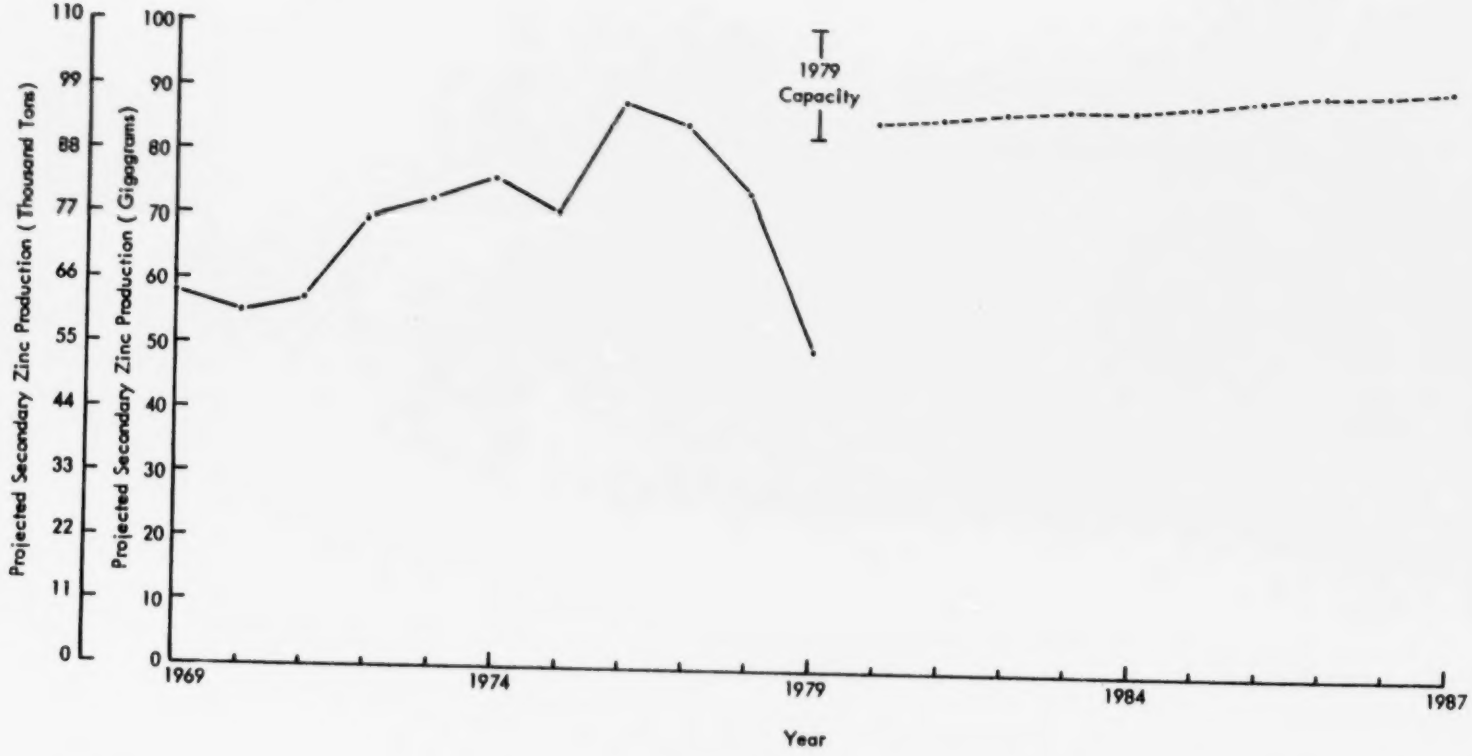


Figure 4-4. Projected secondary zinc production.

For comparison, the Department of Commerce Industry and Trade Administration forecasts a 2.8 percent annual growth in slab zinc consumption for 1977 to 1983,[17] the U.S. Bureau of Mines forecasts a 2.0 percent annual growth in the production of slab zinc from scrap for 1973 to 2000,[18] and Predicasts reports forecasts for growth in consumption of old zinc scrap in the 3.2 to 3.9 percent range.[19]

Generally the consumption of zinc in the United States can be expected to grow with the using industries in the coming years. There are several competitors with zinc to protect steel; also aluminum and plastics compete with galvanized steel, but zinc can be expected to hold its own in most instances. Galvanized steel may make inroads against wood, because of the more rapid increase in wood costs. The weight reduction of automobiles can be expected to deprive zinc of a significant part of its die casting market, as lighter aluminum, magnesium, or plastics materials replace zinc, but an electric automobile powered by a zinc-chloride battery would require 45 kg (100 lb) of zinc.[20] If zinc-chloride or nickel-zinc batteries are widely used to level electrical loads, another significant new market would develop.

Zinc dust has an importance to the secondary zinc industry far beyond its importance to the zinc industry as a whole: it is the one zinc product which has scrap as its principal source. Zinc dust markets were very weak in 1979, but they were also weak from 1970 to 1971 and in 1974 and they recovered. There are many competitors to zinc-rich paints as protective coatings for steel, but the effectiveness of zinc-rich paints should enable them to hold this market as long as their price does not become unreasonable.

The use of zinc oxide in rubber should continue to grow with the rubber industry. The only threat to this market is the possibility of plastic tires. The use of small, long-lasting radial tires will retard growth in this market, however.

In conclusion, the demand for secondary zinc should grow slowly over the next 10 years. The pace of growth is likely to be uneven.

4.2.4 Estimated Industry Expansion

From the point of view of the U.S. zinc industry, the problem is not the level of zinc consumption, it is competition from imports. For more than a decade, more than half of the U.S. slab zinc consumption has come from imports, either of ores or of slab zinc. The imports of ores and concentrates have been steadily decreasing, while the imports of slab zinc have been increasing. In 1971 the zinc content of imported slab zinc equaled the zinc content of imported ores and concentrates. By 1979 the zinc content of imported ores and concentrates were only one-fourth the zinc content of imported slab zinc.[4,17,20]

With the competition from imports, the U.S. zinc industry is experiencing decreasing prices and low operating rates. The U.S. producer zinc price decreased from 86¢/kg (39¢/lb) in 1975 to 68¢/kg (31¢/lb) in 1978.[21] The 1979 price averaged 82¢/kg (37¢/lb).[22] The London Metal Exchange price has been 9 to 15¢/kg (4 to 7¢/lb) less than the U.S. producer price since 1975. The four

electrolytic (primary) zinc plants in the United States operated at 75 percent of capacity in 1978 while the 44 electrolytic plants in the world operated at 76 percent of capacity.[23] The two distillation plants (primary) in the United States operated at 54 percent of capacity in 1978.[24] In 1979 the larger distillation plant, which had accounted for 65 percent of U.S. distillation capacity, was closed by St. Joe Minerals.[25,26] This 201,818 Mg/year (222,466 tons/year plant in Monaca, Pennsylvania, produced 50,000 Mg (55,000 tons) of zinc from scrap at one time. St. Joe Minerals has begun planning for a new primary electrolytic plant, while maintaining customer relations to the extent possible, e.g., by acting as a broker. Since 1972 the electrolytic primary zinc capacity in the United States has increased from 190,000 to 320,000 Mg, (210,000 to 350,000 tons) while the distillation (primary) capacity has decreased from 465,000 to 107,300 Mg (500,000 to 118,300 tons). Only one primary distillation plant remains.

Not only must the secondary zinc industry compete against the U.S. primary zinc industry and foreign zinc producers for markets, it must also compete against them for raw materials. The production of redistilled slab zinc by primary producers has been decreasing but is still more than double the production by secondary producers.[27] The primary electrothermic distillers have a strong incentive to use scrap materials since scrap materials require less energy to process than ore.[5,28] The electrothermic distillation process is more energy intensive than the electrolytic process for ores, requiring 84.38 kJ/g (72.57 million Btu per ton) of zinc in comparison to 69.96 kJ/g (60.17 million Btu per ton).[18] The substitution of scrap for ore is a strategy for an electrothermic primary plant to attempt to remain competitive with an electrolytic plant.

Meanwhile, the exports of zinc scrap have been increasing since 1975. Figure 4-5 shows the exports of zinc scrap for 1965 to 1979.

The U.S. secondary zinc smelters and refiners are estimated from the telephone survey and plant visit to be operating at 50 to 60 percent of capacity. This would imply an annual capacity of 83,000 to 100,000 Mg (92,000 to 110,000 tons). A new secondary zinc plant has been built and is scheduled to begin operations in 1980. Its capacity is confidential, but "small relative to the zinc industry." Of course all secondary plants are small relative to the zinc industry.

The U.S. zinc industry is not in a particularly healthy state today, so there is a potential for more dislocations. The closing of the large electrothermic distillation (primary) plant may result in increased activity in the secondary zinc industry, but there is sufficient slack in the primary industry alone to absorb the closed plant's production without difficulty.

The impact of pollution control on the industry has been substantial in the 1970's and has been at least a part of the reason for plant closings. At present, pollution control is an established part of the industry, but can be expected to continue as a very significant factor relative to modifications of existing plants or construction of new plants. With regard to the latter (new plant construction), relocation of plants to less sensitive air quality control regions is likely to be an important consideration.

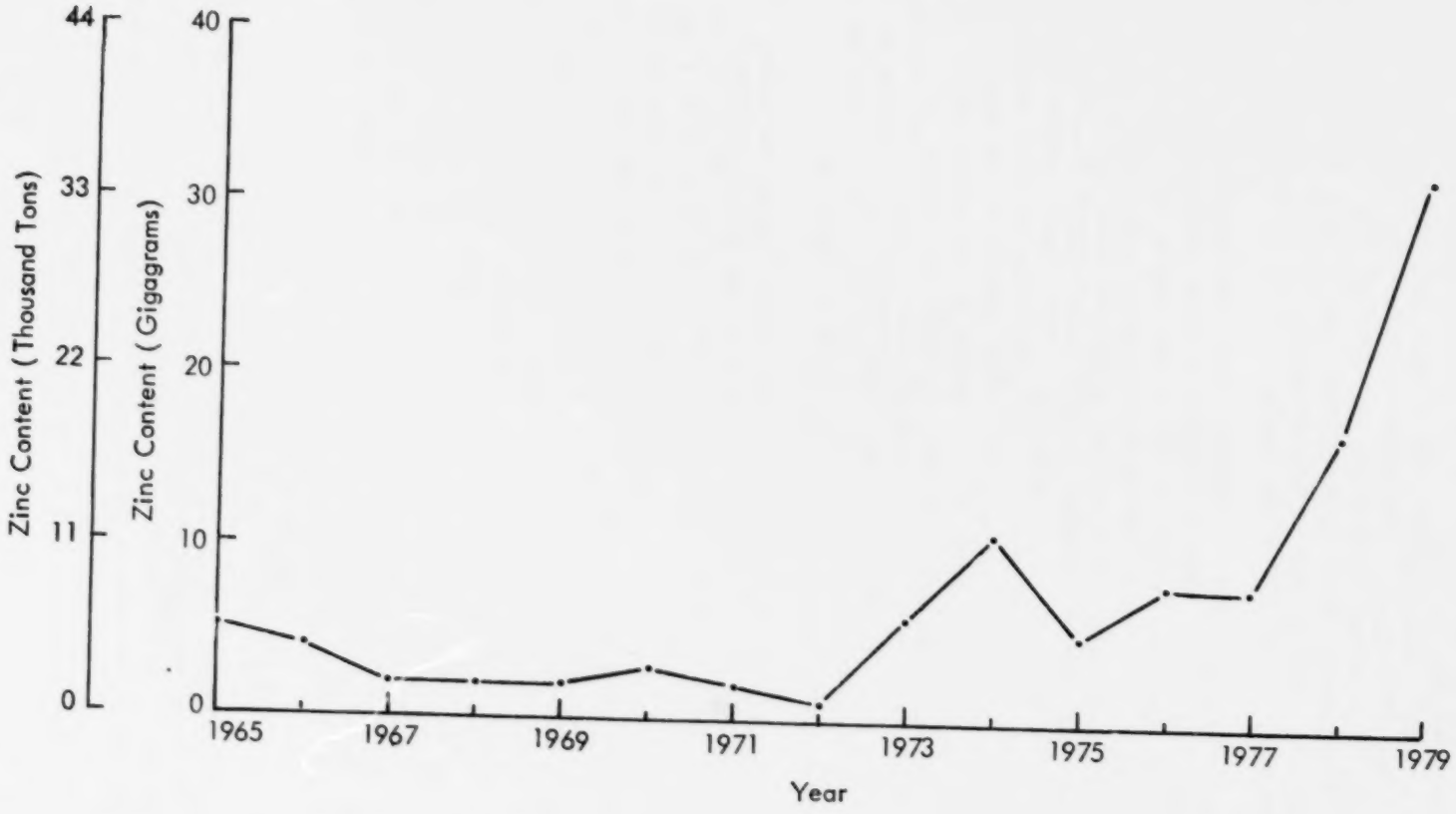


Figure 4-5. Exports of zinc scrap, 1965-1979.

Perhaps the most significant factor relative to the future of existing plants is energy supply and cost. Zinc smelting and refining requires large expenditures of fuel, principally natural gas, and existing plants are not designed for energy efficiency. One plant engineer, for example, expressed a desire to reengineer retort operations to increase fuel efficiency from 8 to 24 percent. High energy costs favor production of zinc from scrap rather than from ore, however. Energy use is approximately 23 kJ/g (20 million Btu per ton) of product,[30] or one-third the energy used by an electrolytic primary plant.

One generally concludes, therefore, that the secondary zinc industry (as well as primary) is in an area in which a holding pattern exists due to significant changes or pending changes in the scrap supply and market, the need to upgrade processes for greater energy efficiencies and reduced costs, and pollution control requirements. The current situation with respect to raw materials supply and the weak product demand in 1979 would appear to point to decreased production in the secondary zinc industry. This factor might well be counterbalanced, however, by an increase in the percentage of zinc recycled and by greater response in specific plants to local supply of raw materials and product demand. This latter philosophy was expressed by one plant executive in general contrast to the negative attitude taken by numerous executives. If the growth projection shown in Figure 4-4 is realized and if the current capacity is in the upper half of its estimated range, there would be no reason to increase secondary zinc capacity in the 1980's. At the most, a single plant one-half the size of the model plant (Section 8) would be sufficient.

In addition to the possibility of expansion in the secondary zinc industry, there is the possibility of replacing part of the present capacity with new sources. The Bureau of Mines list of secondary plants which reported production of redistilled slab zinc[4,29] was reviewed for 1957 to 1978 to check for stability. Three of the plants listed in Table 4-1 have been in continuous production since 1957 or earlier. These three plants account for approximately 35 percent of the industry's capacity. Within the remainder of the industry's capacity there has been some turnover. Thirteen new plants opened in 22 years, while the total slab zinc annual capacity of the reporting plants decreased from 55,000 to 40,000 Mg (61,000 to 50,000 tons). There were 17 openings and 21 closings, but in some instances, a plant closed and reopened. There were seven closings in 1973 and four closings in 1978, and there were four openings in 1961, seven openings in 1975, and four openings in 1977. This replacement of capacity appears to result from economic conditions in the industry, not from change in technology. This is indicated by the clustering and by the repeated exit and reentry of certain companies.

4.3 SECONDARY ZINC PROCESSES

An overall flow diagram for secondary zinc processing is depicted in Figure 4-6. As shown in Figure 4-6, the process consists of three distinct stages: scrap preparation, distillation and remelting; and product finishing. These major stages are discussed in detail in the following sections.

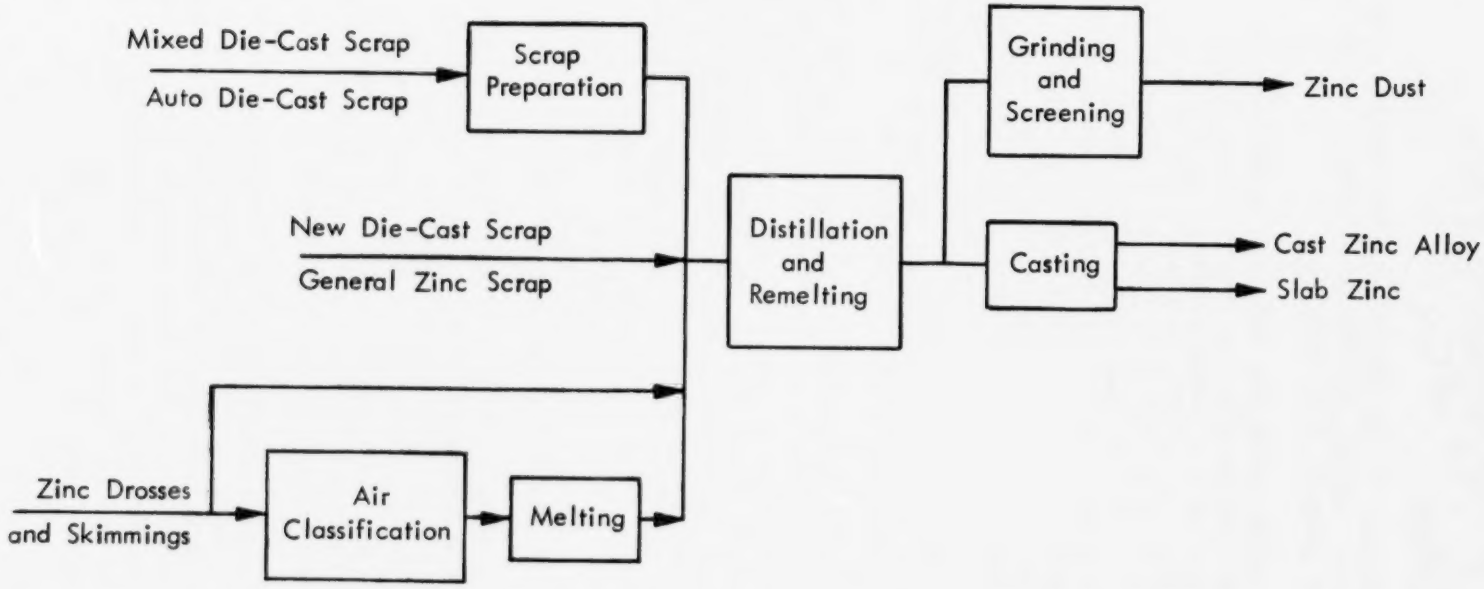


Figure 4-6. Flow diagram for secondary zinc processing.

4.3.1 Scrap Preparation

Zinc scrap consumed in the secondary zinc industry can be grouped into four broad categories, namely, galvanizers' scrap, new die-cast scrap, mixed die-cast scrap, and general zinc scrap.

Galvanizers' scrap (primarily drosses, skimmings, sal skimmings, and ashes) are largely shipped from galvanizing operations in drums or solid blocks to the scrap-consuming plant. In many plants, they are charged to the distillation furnace either directly or after first being melted in a separate operation. Some plants dry mill and air classify the zinc skimmings to separate the metallic zinc from zinc oxide. In other plants, skimmings are crushed and then treated in the following manner. The crushed skimmings are washed with water to separate nonmetals as a slurry and allow zinc-containing metal particles to settle out; the slurry is then treated with Na_2CO_3 to convert chlorides (mainly $ZnCl_2$) to NaCl, forming insoluble $Zn(OH)_2$. Most of the NaCl is separated from the insoluble residues by filtration and settling; the residue is dried and calcined in a kiln to convert $Zn(OH)_2$ to ZnO by driving off H_2O and vaporizing any remaining $ZnCl_2$. The calcined product is mostly ZnO and is suitable for smelting. The kiln fume is collected and recycled.

New die-cast scrap, classified as prompt industrial scrap, consists of castings discarded as a result of manufacturing defects at the die-casting plant. There are two types of new die-cast scrap. Clean die-cast scrap is well segregated and can be melted at the scrap processing plant to produce a product that meets market specifications. Off-specification die-cast scrap is not so well segregated as clean die-cast scrap and cannot be melted into a product meeting market specifications. It is normally refined and blended to meet market specifications. General zinc scrap includes such items as clippings and engravers' plates. This scrap category is a relatively minor element in the secondary zinc industry. New die-cast scrap and general zinc scrap usually require no preparation before being consumed by a secondary zinc smelter.

Mixed die-cast scrap, which is classified as obsolete scrap, consists of such products as auto shredders' scrap, old auto parts, and old appliance parts. It forms a substantial portion of the total zinc scrap supply. The scrap from auto shredders is sometimes classifed into a separate category, such as auto die-cast scrap. Mixed die-cast scrap and auto die-cast scrap contain a large amount of ferrous and nonferrous material, and they are pretreated in a sweating process to produce a low purity zinc product.

Sweat processing is accomplished by charging the scrap into a sweating furnace. In the furnace, heat (usually from natural gas) is applied to the scrap materials to melt and separate metallic zinc from metal attachments, having higher melting points, and from nonmetallic residues. Any organic materials in the scrap are also burned off during sweating. The charge may be worked by agitation or stirring during melting; and chloride flux may be present either as residual flux, in charged residual scrap, or as flux added to the charge. Working and fluxing of the charge are done to help effect the desired metal separation.

A molten metal bath is formed from the metallic zinc (with dissolved alloy metals). Nonmetallic residues, along with some plating, form above the molten-metal bath surface and are skimmed off. Unmeltable attachments settle to the bottom and are removed. The molten metal may then be (a) cast directly into blocks for subsequent further processing, or (b) fed directly to a distillation furnace, or (c) it may sampled and analyzed, and then alloyed by adding metals to obtain specification composition, and then cast as ingots.

Several types of furnaces are used for sweating zinc-scrap materials and they are discussed in the following order:

1. Reverberatory furnaces
2. Rotary furnaces
3. Melting-kettle (or kettle) furnaces
4. Muffle furnaces
5. Electric-resistance furnaces

4.3.1.1 Reverberatory Furnace. The reverberatory furnace has a general box configuration with a sloped bottom (hearth). It is used to process both metallic and residual zinc scrap materials, which are charged into the furnace and rest on the hearth. Natural gas or fuel oil burners are located in the upper part of the furnace; combustion of fuel above the charge supplies heat to burn off organic substances, as well as heat to melt the zinc alloys in the charge. Furnaces are designed and burners are positioned to minimize flame impingement on the charge and to reduce oxidation and entrainment of metal oxide particles. As zinc alloys melt, they separate from unmeltables and flow downward over the hearth. Bath temperatures in reverberatory furnaces are usually around 800K (1000°F). Metal flows from the furnace as it melts; and, at intervals, unmeltables are raked out and additional process material charged.

Reverberatory furnaces may be independent units or they may be integral with distillation furnaces. Consideration here is limited to the independent type of unit where molten metal from the hearth flows through a spout into ladles or kettles. The metal may then be processed further to obtain a specification alloy, or it may be fed to a distillation furnace.

Sweat processing in a reverberatory furnace is shown schematically in Figure 4-7, along with emissions and emission points. These emission points and effluents from these points are detailed further in Table 4-6.

4.3.1.2 Rotary Furnace. The melting unit of the rotary-type furnace consists of a hollow cylinder mounted with its lengthwise axis sloped at a small angle from horizontal. During operation, this cylinder is mechanically rotated on that axis and internally heated by gas or oil burners. Scrap materials are fed into the high end of the melting cylinder. As the cylinder rotates, zinc melts and flows out through openings in the low end, usually into a kettle where residues are skimmed off. Unmeltables are separated from the bath by tumbling

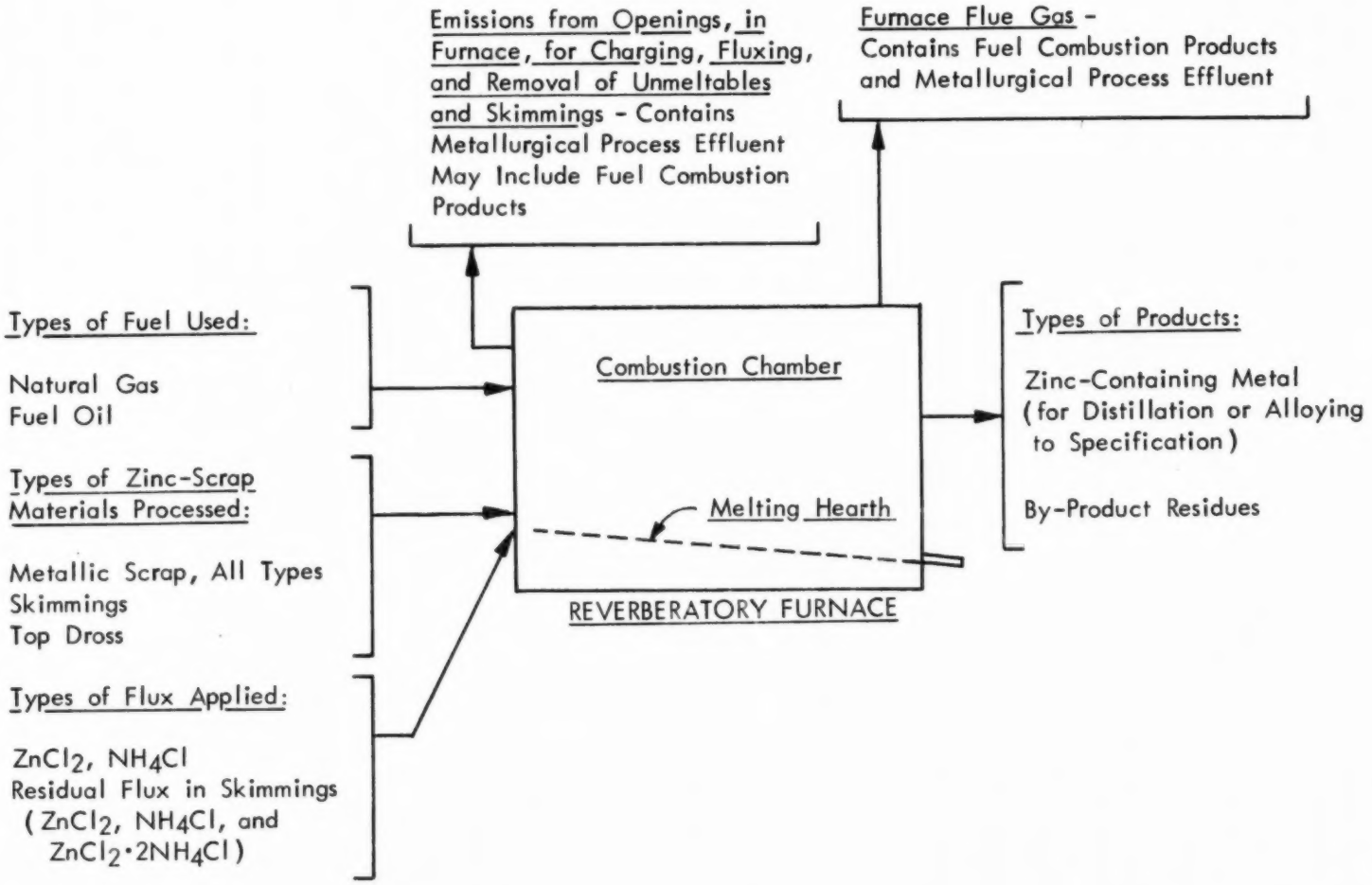

Emissions from Openings, in Furnace, for Charging, Fluxing, and Removal of Unmeltables and Skimmings - Contains Metallurgical Process Effluent May Include Fuel Combustion Products
Furnace Flue Gas - Contains Fuel Combustion Products and Metallurgical Process Effluent
Types of Fuel Used:
Natural Gas
Fuel Oil
Types of Zinc-Scrap Materials Processed:
Metallic Scrap, All Types
Skimmings
Top Dross
Types of Flux Applied:
$ZnCl_2$, NH_4Cl
Residual Flux in Skimmings ($ZnCl_2$, NH_4Cl, and $ZnCl_2 \cdot 2NH_4Cl$)
Combustion Chamber
Melting Hearth
REVERBERATORY FURNACE
Types of Products:
Zinc-Containing Metal (for Distillation or Alloying to Specification)
By-Product Residues

Figure 4-7. Sweat processing of zinc-scrap materials in reverberatory melting furnace.

TABLE 4-6. EMISSION POINTS AND EFFLUENTS OF SECONDARY ZINC-SWEAT PROCESSES

Process (defined by type of furnace used)	Emitting process equipment unit	Emission point of process equipment unit	Constituents of effluents from emission points
Kettle Furnace	Melt kettle	Top of melt kettle (or surface of metallurgical process bath, formed from charge).	A. Emissions from process charge. 1. Products of combustion or thermal decomposition of organic materials in charge. 2. Emissions derived from metals, fluxes, and residues in metallurgical process bath, including metal oxides resulting from presence of air contacting metal. B. Air induced or infiltrated into exhaust effluent stream.
	Combustion chamber	Combustion chamber vent	A. Products of combustion of fuel (usually natural gas).
Reverberatory Furnace	Combustion chamber, containing melting hearth. (May also be referred to as "sweating chamber".)	Furnace flue (exhausting combustion chamber).	A. 1.-2. Emissions from process charge (same items as listed above). B. Air induced or infiltrated into furnace, thence into flue. (would be in excess of air consumed in combustion). C. Products of combustion of fuel (usually natural gas).
		Openings for charging and fluxing; and removal of unmeltables and skimmings.	A. 1.-2.; B.; and C. Same items as listed above for furnace flue. These effluents are formed from (1) gases escaping from the furnace; (2) emissions from the molten metal and skimmings being withdrawn from furnace with unmeltables; and (3) ambient air.
Rotary Furnace	Rotating, cylindrical melt unit. (May also be referred to as "sweating chamber" or "combustion chamber".)	Furnace flue (high end of melting cylinder).	A. 1.-2.; B.; and C. Same as listed above for flue of reverberatory furnace, except emissions derived from flux are not normally contained in rotary furnace effluent.

them out of the low end of the cylinder or by manual raking and scraping. Rotary furnace bath temperatures are usually lower than those of reverberatory furnaces because rotation helps separate molten zinc from unmeltables, maintain molten zinc and alloy metals in solution, and use heat more efficiently by avoiding localized high temperature zones, thereby allowing lower bath temperatures to be applied. The collected zinc-containing metal may then be transferred to a distillation furnace, or its composition may be adjusted to an alloy specification.

4.3.1.3 Kettle Furnace. The kettle furnace consists of a melting vessel (kettle), made of cast iron in most cases, mounted over a combustion chamber. Scrap materials, which may include metallic and/or residual types, are charged into the kettle. The metallurgical-process bath is formed as zinciferous metal is melted and residues form above the molten metal surface. Operating temperatures of kettle-process baths range from 700 to 800K (800 to 1000°F). Production is on a batch basis, with one process heat requiring around 6 to 8 hr to process and pour. A molten heel may be retained as finished alloy is removed from furnaces and additional scrap (process material) charged.

Normally, products of fuel combustion are exhausted separately from emissions of the metallurgical-process bath, through separate venting of the combustion chamber. Natural gas is the generally used fuel (fuel oil being used in a smaller number of cases).

Sweat processing in a kettle furnace is shown schematically in Figure 4-8, along with emissions and emission points. Emission points and effluents emitted from these points are detailed further in Table 4-6.

4.3.1.4 Muffle Furnace. In the muffle furnace, as applied to sweating processes, combustion gases are separated from charged zinc-scrap materials by a "muffle." This design permits separation of combustion products from those emissions derived from charged zinc-scrap materials and flux. In this respect, the muffle furnace is similar to the kettle furnace.

4.3.1.5 Electric-Resistance Furnace. Electric-resistance furnaces are used in a small number of plants for processing clean, scrap-derived zinc metal.

4.3.2 Remelting and Distillation

Zinc scrap is processed into the final products by three schemes: pot melting, retort distillation, and muffle furnace distillation. Each method is discussed separately in the following subsections.

4.3.2.1 Pot Melting. Pot melting of zinc die-cast scrap involves melting either well segregated or off-specification zinc die-cast scrap in a steel pot furnace. Pot melting is a simple melting scheme in which heat is supplied (usually from natural gas) to the charge by indirect heating. Recovery of more than 90 percent is achieved with losses occurring principally as zinc fumes and skimmings. The recovered zinc is cast into zinc slabs or alloyed and cast into zinc alloy ingots.

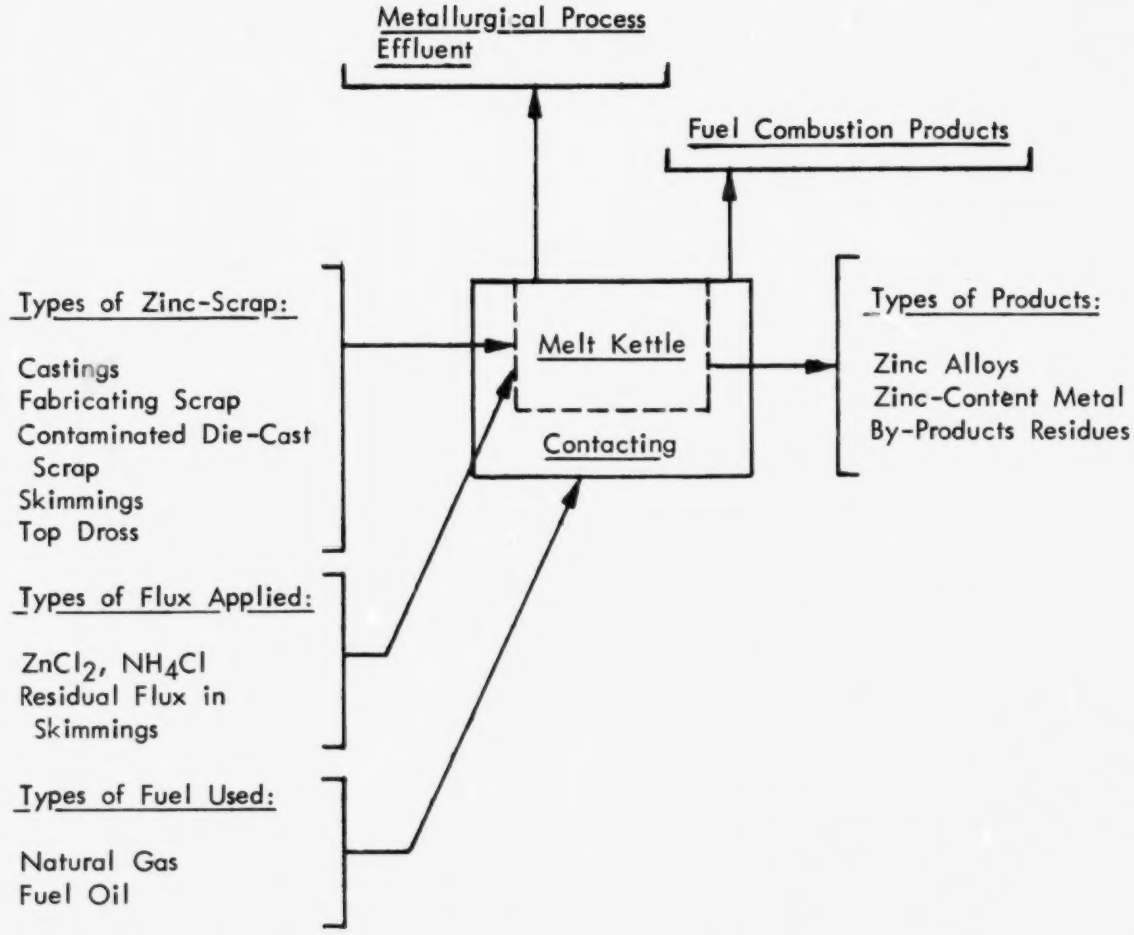


Figure 4-8. Sweat processing of zinc-scrap materials in kettle melting furnace.

4.3.2.2 Retort Distillation. Belgian and bottle retorts are used to distill zinc scrap. Belgian retorts are used to reduce zinc oxide to metallic zinc. Bottle retorts, used for batch ditillations, reclaim zinc from alloys, refire zinc, make powdered zinc, and make zinc oxide. Although zinc boils at 1180K (1665°F), most retort furnaces are operated at temperatures ranging from 1250 to 1520K (1800 to 2280°F). Zinc vapor burns spontaneously in air; therefore, air must be excluded from the retort and condenser when metallic zinc is the desired product. Condensers are designed, either for rapid cooling of the zinc vapors to a temperature below the melting point to produce powdered zinc, or for slower cooling to a temperature above the melting point to produce liquid zinc. When the desired product is zinc oxide, the condenser is bypassed and the vapor is discharged into a stream of air where spontaneous combustion converts the zinc to zinc oxide. Excess air is used, not only to ensure sufficient oxygen for the combustion, but also to cool the products of combustion and convey the oxide to a suitable collector.

4.3.2.2.1 Belgian retort. The Belgian retort furnace, shown in Figure 4-9, is one of several horizontal retort furnaces that have been for many years the most common device for the reduction of zinc. (No current usage of Belgian retorts in the secondary industry was uncovered in the survey.) A typical Belgian retort is about 20 cm (8 in.) in internal diameter and from 122 to 152 cm (48 to 60 in.) long. One end is closed and a conical shaped clay condenser from 46 to 61 cm (18 to 24 in.) long is attached to the open end. The retorts are arranged in banks with rows four to seven high and as many retorts in a row as are needed to obtain the desired production. The retorts are generally gas fired.

The retorts are charged with a mixture of zinc oxide and powdered coke. Since these materials are powdered, water is added to facilitate charging and allow the mixture to be packed tightly into the retort. Three to four times more carbon than is needed for the reduction reaction is used.

After the charging, the condensers are replaced and their mouths stuffed with a porous material. A small hole is left through the stuffing to allow moisture and unwanted volatile materials to escape.

The air contaminants emitted vary in composition and concentration during the operating cycle of Belgian retorts. During the charging operation, very low concentrations are emitted. After zinc begins to form, both carbon monoxide and zinc vapors are discharged. These emissions burn to form gaseous carbon dioxide and solid zinc oxide. During the heating cycle, zinc is poured from the condensers about three times at 6- to 7-hr intervals. The amount of zinc vapors discharged increases during the tapping operation. Before the spent charge is removed from the retorts, the temperature of the retorts is lowered, but zinc fumes and dust from the spent charge are discharged to the atmosphere.

4.3.2.2.2 Bottle retort. The bottle retort furnace (Figure 4-10) consists of pear-shaped, graphite retort, which may be 1.5 meters (5 ft) long by 0.6 meter (2 ft) in diameter at the closed end by 0.5 meter (1-1/2 ft) in diameter at the open end and 0.9 meter (3 ft) in diameter at its widest cross-section.

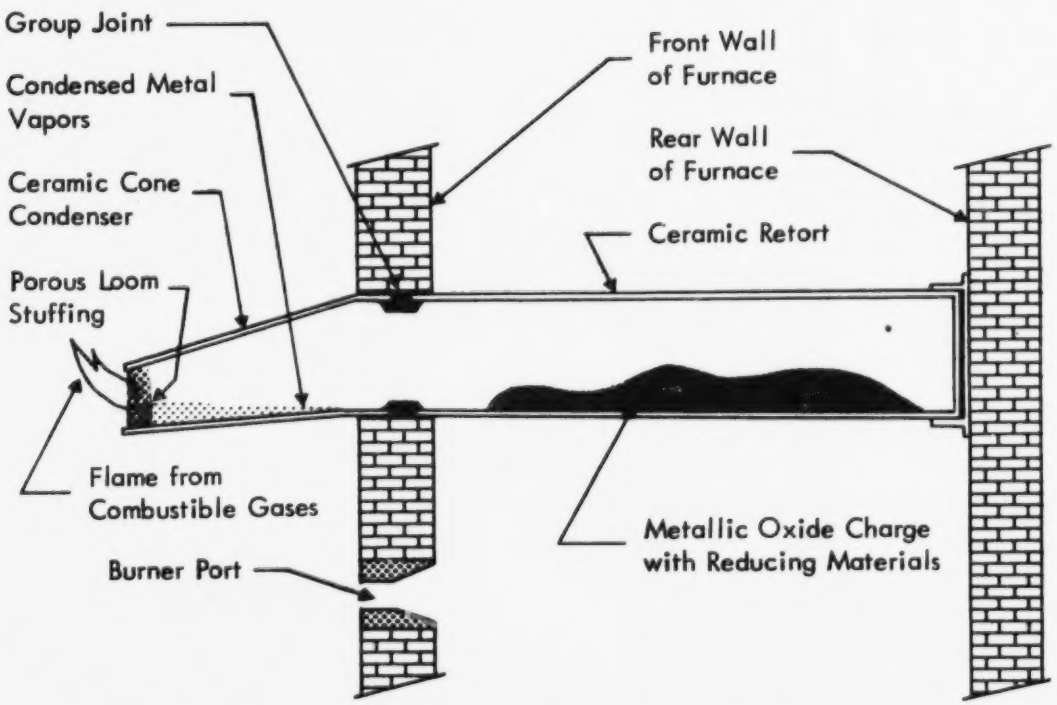


Figure 4-9. Diagram showing one bank of a Belgian retort furnace.

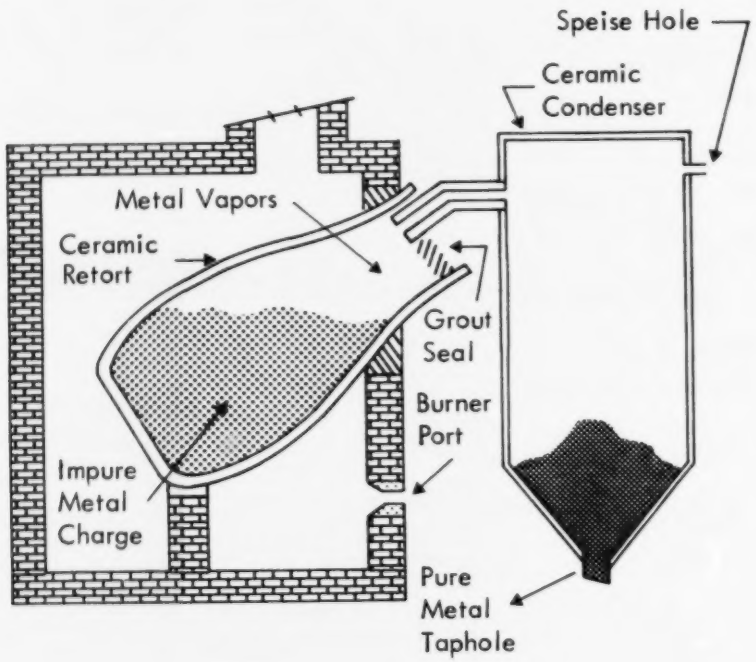


Figure 4-10. Zinc: retort distillation furnace.

Normally the retort is encased in a brick furnace with only the open end protruding and it is heated externally with gas- or oil-fired burners. The retorts are charged with molten, impure zinc through the open end, and a condenser is attached to the opening to receive and condense the zinc vapors. After the distillation is completed, the condenser is moved away, the residue is removed from the retort, and a new batch is started.

The vaporized zinc is either conducted to a condenser or discharged through an orifice into a stream of air. Two type of condensers are used--a brick-lined steel condenser operated at from 690 to 818K (780 to 1012°F) to condense the vapor to liquid zinc, or a larger, unlined steel condenser that cools the vapor to solid zinc. The latter condenser is used to manufacture powdered zinc. The condensers must be operated at a slight positive pressure to keep air from entering them and oxidizing the zinc.

When it is desired to make zinc oxide, the vapor from a retort is discharged through an orifice into a stream of air where zinc oxide is formed inside a refractory-lined chamber. The combustion gases and air, which bear the oxide particles, are then carried to a baghouse collector where the powdered oxide is collected.

During the 24-hr cycle of the distillation retorts, zinc vapors escape from the retort (a) when the residue from the preceding batch is removed from the retort and a new batch is charged, and (b) when the second charge is added to the retort. As the zinc vapors mix with air, they oxidize and form a dense cloud of zinc oxide fumes. Air contaminants are discharged for about 1 hr each time the charging hole is open. When zinc is actually being distilled, no fumes escape from the retort; however, a small amount of zinc oxide escapes from the speise hole in the condenser. Although the emission rate is low, air contaminants are discharged for about 20 hr/day.

Emission points in the retort-furnace system are listed, with emissions from those points in Table 4-7.

4.3.2.3 Muffle Furnace Distillation. Muffle furnaces (Figure 4-11) are continuously fed retort furnaces. They generally have a much greater vaporizing capacity than either Belgian retorts or bottle retorts do, and they are operated continuously for several days at a time. Heat for vaporization is supplied by gas-or oil-fired burners by conduction and radiation through a silicon carbide arch that separates the zinc vapors and the products of combustion. Molten zinc from either a melting pot or sweat furnace is charged through a feed well that also acts as an air lock. The zinc vapors are conducted to a condenser where purified liquid zinc is collected, or the condenser is bypassed and the vapors are discharged through an orifice into a stream of air where zinc oxide is formed. Muffle furnaces can produce zinc of 99.8 percent purity and ZnO of 99.9 percent purity. Recoveries of more than 90 percent are usually obtained. Losses occur as entrapped zinc in the unmelted scrap and in the fumes.

Emission points and effluents from the muffle furnace system are detailed in Table 4-7.

TABLE 4-7. EMISSION POINTS AND EFFLUENTS OF SECONDARY ZINC-DISTILLATION PROCESSES

Process (defined by furnace system used)	Emitting process equipment unit	Emission point of process equipment unit	Constituents of effluents from emission points
Retort Furnace Sytem	Distillation retort	Opening of distillation retort. (Emissions occur during rmeoval of distillation residues. This opening may be referred to as "charging holes." It is used for applying charge to retort and remving residues.)	A. Emissions from distillation residues. 1. ZnO (makes up most of emitted particulates). 2. Oxides of other metals (mainly Al_2O_3) - small amounts. B. Ambient air.
	Combustion chamber	Combustion chamber vent.	A. Products of combustion of fuel (usually natural gas).
	Condenser	Pressure relief valve. (used to retain positive pressure and exclude air from condenser).	A. Emissions from vapors distilled from retort charge. partly oxidized by residual air in retort and condenser system. 1. ZnO particulate. 2. Metallic zinc dust (particulate). 3. Chloride particulates, derived from flux. (Very small amounts may occur when dross is charged to retort.) B. N_2 from residual air in retort and condenser.
	Condenser	"Speise" hole. (Used instead of pressure relief valve for same purpose. Zn vapor escaping from condenser through speise hole is ignited in air, producing ZnO particulates.)	A. Emissions from vapors distilled from retort charge and oxidized. 1. ZnO particulate, nearly pure. (The charge to retort is of molten metal which would not produce chloride emissions - APEM, p. 296.) B. N_2 from residual air in retort and condenser. C. Ambient air
Muffle Furnace System	Melt unit (reverberatory furnace)	Flue of melt-unit combustion chamber.	A. Emissions from melt-unit charge. 1. Products of combustion or thermal decomposition of organic materials in charge. 2. Emissions derived from metals and residues (usually no flux) in metallurgical-process bath, including metal oxides resulting from presence of air. B. Air induced or infiltrated into melt unit, thence into flue. (Would be in excess of air consumed in combustion.) C. Products of combustion of fuel (usually natural gas), burned in melt unit and vaporizing unit.
		Openings in melt unit for charging scrap material and removing unmeltables and skimmings.	A. 1., 2.; B.; and C. Same items as listed above for furnace flue. These effluents are formed from (1) gases escaping from the melt unit; (2) emissions from the molten metal and skimmings being withdrawn from melt unit with unmeltables; and (3) ambient air.
	Vaporizing unit (muffle furnace)	Tap hole of vaporizing unit. (Emissions occur during removal of distillation residue.)	A. Emissions from distillation residues. 1. ZnO particulate, nearly pure - APEM, p. 299). B. Ambient air.

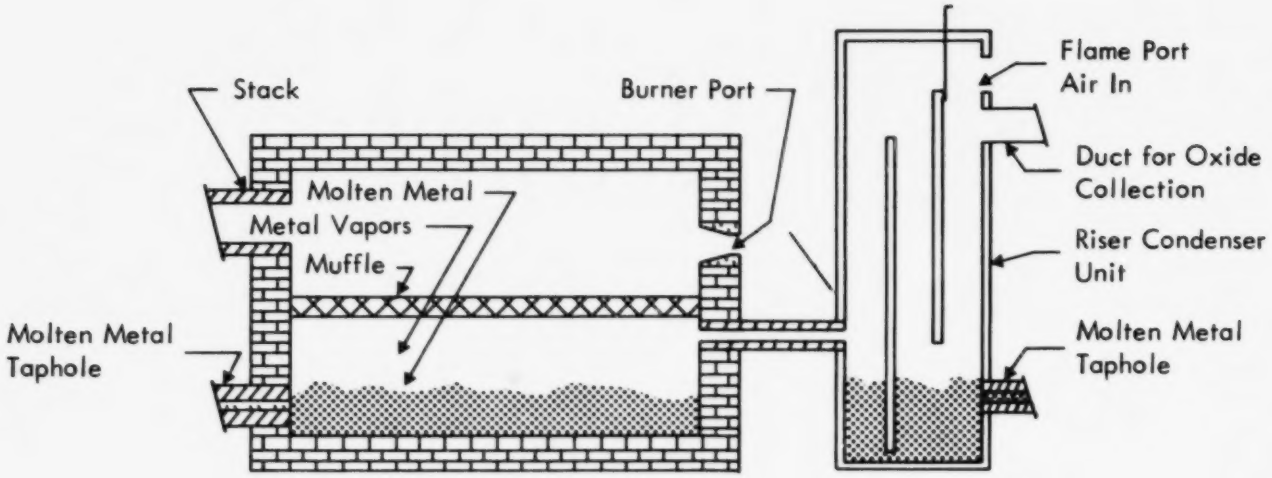


Figure 4-11. Muffle furnace and condenser.

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5.0 AIR EMISSIONS IN THE SOURCE CATEGORY

This chapter identifies types and quantities of air emissions in a representative secondary zinc plant. There are three basic types of operations in secondary zinc plants:

1. Distillation processes in muffle furnaces or retorts. In this type of equipment, the charge is indirectly heated. Combustion gases are vented without control of emissions, but since natural gas is the fuel of choice, particulate emissions are negligible in the flue gas, and nitrogen and sulfur oxides emissions are those expected of natural gas combustion. The principal emissions occur when the furnace or retort is broken; a hood system collects particulates released at this point. These are drawn together with hot gases and dilution air into baghouses. With multiple sources, as nearly always is the case, a network of dampered hoods and ductwork is employed, and the operation (breaking of furnaces) is staggered so the emission control system is not overloaded at any one time, and so that adequate draft exists at emission sources.

2. Sweat furnaces (kettle, reverberatory, rotary kiln) operate with direct heating, at 800 to 900K (1000 to 1200°F) furnace temperature, and with combustion gases vented to baghouses. Emissions generated from sweating operations are a function of the quality and prior history of the charge. Particularly significant is the quantity of organic matter (grease, coatings, etc.) which partially burns in the sweating operation to both particulate and gaseous products of incomplete combustion. An afterburner is needed to take care of this problem, at the expense of approximately doubling fuel costs and creating added volumes of hot gases which must be cooled by dilution prior to the baghouse.

3. Pot furnace operations. These are oriented primarily toward alloy production, with recycle zinc being usually used as a small percentage (5 to 15 percent) of the total charge, and with scrap being of high quality. Control of emissions is nearly always effected with hood, vent network and baghouse systems. Pot furnace operations are restricted to only a few plants, with alloying being the only zinc operation in the plant and with typically about 90 Mg (100 tons) of recycle zinc processed. For this reason, such operations are not included in the representative zinc plant, which accordingly has two basic operations--sweating and distillation.

Other than the easily identified emission sources, namely combustion gas streams from sweating operations, and emissions which take place when any of the basic plant equipment is "broken," emissions may occur when furnaces develop

leaks, when certain operating procedures such as utilization of poke rods release spot emissions, during product and residue handling/conveying, and during charging operations. These latter emissions are largely uncontrolled, except to the extent that the in-building air flows (850 standard cubic meters per minute (30,000 scfm) or greater to a baghouse complex) provide control. One plant reports that hot ash is blanketed manually with cool ash to minimize dust emissions.

The pollution control systems of hoods, ductwork, and baghouses in all the plants surveyed is designed for cost effective control of total operations, as opposed to a much more costly system in which each source is controlled independently of others. All sources are not necessarily directed to a common baghouse via a universal ductwork system. However, the baghouses, ductwork, and hoods are designed to provide required airflows, and intermingling of air streams, on the basis that specified ventilating air streams will suffice to handle all sources, some on a continuous basis, but many on an intermittent but scheduled basis. The effectiveness of this mode of operation is to a considerable extent governed by how well the operations are actually scheduled to prevent temporary overloads or an undue burden on the air moving system, and on operator diligence in management of dampers. The above considerations were cited most often by regulatory agencies, and were universally recognized as a problem by plant management, i.e., regulatory agency staff generally expressed satisfaction with system design and with its operation, if it and the plant complex is properly operated.

5.1 PLANT AND PROCESS EMISSIONS

5.1.1 Particulate

Emission data and emission factors were obtained primarily from traditional sources such as AP-42 and the National Environmental Data System. Limited measured data were obtained from California regulatory agencies. These latter data corroborate other data or estimates, but only to a very limited extent. Engineering judgment is the basis for most of the estimates, and there is a scarcity of actual information which permits reliable assessment of uncontrolled and controlled emissions.

Uncontrolled emission factors reported for various types of operations are given in Table 5.1.

These data indicate that distillation operations (retorts and muffle furnaces) exhibit the greatest emissions (22 to 24 kg/Mg, 45 to 47 lb/ton); that sweating operations with clean scrap have a negligible potential for particulate emissions, but about 6 to 16 kg/Mg (11-32 lb/ton) as the quality of scrap deteriorates. No data are pesented for rotary sweat furnaces; one data point for measured emissions from a rotary furnace[1] indicates uncontrolled emissions, at the afterburner inlet, to be in the range of 25 to 40 kg/Mg (50 to 80 lb/ton). The only data point for uncontrolled particulate concentration was obtained from the same test--12.77 g/scm (5.58 gr/scf), corresponding to 53 kg/hr (117 lb/hr). Associated data for baghouse exit gases are 0.011 g/scm (0.005 gr/scf) and 0.4 kg/hr (0.88 lb/hr), which corresponds to an overall control efficiency of 99.24 percent, due in part to the afterburner, and in part to the baghouse.

TABLE 5.1. UNCONTROLLED PARTICULATE EMISSION FACTORS FOR SECONDARY ZINC SMELTING

Furnace	Emissions	
	lb/ton product	kg/Mg product
Retort	47	23.5
Muffle	45	22.5
Pot	0.1	0.05
Kettle sweat		
Clean scrap	Neg.	Neg.
General scrap	11	5.5
Residual scrap	25	12.5
Reverberatory sweat		
Clean scrap	Neg.	Neg.
General scrap	13	6.5
Residual scrap	32	16

The uncontrolled particulate emission rate for the rotary furnace corresponds to an emission factor of 25 to 40 kg/Mg (50 to 80 lb/ton) of product, higher than the rates of up to 16 kg/Mg (32 lb/ton) of Table 5-1 reported for sweating operations.

Annual controlled particulate emissions from retorts, muffle furnaces and sweating operations calculated and reported in NEDS for individual operations producing 300 to 2,500 Mg/year (600 to 5,000 tons/year) of product ranged from a lower value of 0.5 Mg/year to about 5 Mg/year (1 to 10 tons/year); corresponding uncontrolled emissions calculated by factoring in control efficiencies (98 to 99 percent) ranged from about 7 to 90 kg/Mg (15 to 180 lb/ton).

Efficiencies reported in NEDS for control of particulates were as low as 95 percent, but commonly were 98 to 99 percent. Efficiencies of 98 to 99 percent are commonly accepted as being achievable by industry, given proper maintenace of baghouses. Actual efficiencies in the overall control of particulates are a function of effectiveness in entraining particulates in air streams at the source, and in maintaining overall operations to eliminate periodic system overloads.

Estimates of uncontrolled and controlled particulates for the entire industry are presented in Table 5-2. These data are based on emissions factors of Table 5-1, and a control efficiency of 97 percent. Total uncontrolled particulates are about 1,200 Mg (1,300 tons) per year, and controlled emissions, 36 Mg (40 tons), with a majority of emissions coming from distillation furnaces.

Emissions estimated for representative plants are shown in Table 5-3. These estimates indicate that a larger, integrated plant can be expected to

TABLE 5-2. ESTIMATES OF NATIONAL ANNUAL PARTICULATE EMISSIONS BY PROCESS TYPE

	Production Mg/year (tons/year)	Emissions, Mg (ton) Uncontrolled	Emissions, Mg (ton) Controlled (97%)
Zinc produced by sweat processes	25,400 (28,000)	190 (210)	5.5 (6)
Zinc produced by pot furnaces			
Total zinc	9,000 (10,000)	0.5 (0.5)	0.02 (0.02)
Recycle zinc	900 (1,000)		
Distilled zinc[a]	44,500 (49,000)		
Muffle furnaces	23,000 (25,000)	511 (562)	15.5 (17)
Retorts	22,000 (24,000)	491 (540)	14.5 (16)
Zinc processed[b]	72,000 (79,000)		
Total emission		1,200 (1,320)	36 (40)

[a] Distilled zinc products: slab/ingots, dust, oxide.
[b] Includes virgin zinc, plus double processing of sweat zinc.

TABLE 5-3. ESTIMATES OF EMISSIONS FROM REPRESENTATIVE PLANTS

Plant type	Production Mg/year (tons/year)	Mg (tons of controlled emissions) 97% efficiency	
Retorts or muffle furnaces	3,600 (4,000)	2.7 (3)	
Integrating sweating, distillation	8,200 (9,000) sweating 13,600 (15,000) distillation	1.8 (2)	7.3 (8[a])
Total		11 (12)	16.3 (18[a])
Sweating	8,200 (9,000)	1.8 (2)	7.3 (8[a])
Pot furnace	1,800 (2,000)	4.5 kg (10 lb)	

[a] Estimates obtained with emission factor of 30 kg/Mg (60 lb/ton) from sweating operations.

emit 9 to 18 Mg (10 to 20 tons) annually of particulates; that a pot furnace/alloy production operation should emit negligible particulates; and that representative single purpose (sweating or distillation) plants can be expected to emit 2 to 7 Mg/year (2 to 8 tons/year) depending on plant type and assumptions regarding emission factors.

Emissions for specific plants surveyed in the study cannot in several cases be estimated with confidence due to the unavailability of production data and/or process information. The estimates in Table 5-4 are provided with this qualification. The estimates range from less than 1 Mg/year/plant (1 ton/year/plant) to about 11 Mg/year (12 tons/year) from a large plant.

5.1.2 NO_x Emissions

Data on NO_x emissions are limited to data recorded in NEDS. These data indicate that NO_x emissions are of the order of 1 kg/1,000 kg (1 ton/1,000 tons) of product for distillation furnaces, and 1 kg/2,000 to 3,000 kg (1 ton/2,000 to 3,000 tons) for sweat furnaces. The lower values for sweat furnaces reflect both the lower temperatures of the sweating operations (800 to 900K (1000 to 1200°F)) versus 1375 to 1475K (2000 to 2200°F) and lower fuel usage.

Application of these factors yields NO_x emissions for the industry of 54 to 64 Mg/year (60 to 70 tons/year). A sweating operation producing 9,000 Mg/year (10,000 tons/year) will emit on the order of 4 to 5 Mg/year (4 to 5 tons/year) of NO_x.

A large integrated sweating and distillation plant (15,000 Mg/year (16,000 ton/year)) of distilled zinc) will emit about 18 Mg (20 tons) of NO_x, while the more average plant sized at 4,000 to 4,000 Mg/year (4,000 to 6,000 tons/year) will emit 5 to 6 Mg (5 to 7 tons) of NO_x annually.

Neither nitrogen oxides or sulfur oxides are controlled by the industry. Sinc natural gas is uniformly used in the industry, sulfur oxide emissions are minimal.

An adequate data base is not available to estimate hydrocarbon emissions. These can be expected principally from sweating operations, but are reduced in quantity and concentration by afterburners.

TABLE 5-4. ESTIMATED EMISSIONS FROM SPECIFIC SECONDARY ZINC PLANTS

Refining operations	Annual production		Uncontrolled emissions		Controlled emissions, 97%	
	Mg	Tons	Mg	Tons	Mg	Tons
California	14,500	16,000	380	420	11.5	12.6
California	3,640	4,000	95	105	2.8	3.1
Texas	4,100	4,500	91	100	2.7	3.0
Oklahoma	5,000	5,500	114	125	3.4	3.7
New Jersey	3,640	4,000	82	90	2.4	2.7
Pennsylvania	3,640	4,000	82	90	2.4	2.7
West Virginia	3,640	4,000	82	90	2.4	2.7
Illinois	2,700	3,000	59	65	1.8	2.0
Alabama	2,700	3,000	59	65	1.8	2.0
Ohio	900	1,000	18	20	0.5	0.6
Sweating						
Michigan	13,600	15,000	102	112	3.1	3.4
New York	4,500	5,000	34	37	1.0	1.1

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6.0 EMISSIONS CONTROL SYSTEMS

6.1 CURRENT CONTROL TECHNOLOGY PRACTICES

Sources of information on emissions control systems were primarily telephone contacts with plant personnel and state and local regulatory agencies. Control systems are in operation in all the plants surveyed for particulate emissions from the several types of furnaces--pot, kettle, reverberatory and rotary sweat furnaces, and muffle and retort distillation furnaces. Afterburners in some plants augment baghouse control for sweating operations. Only very limited use is made of electrostatic precipitators and wet scrubbers.

Standard practice in the industry involves baghouse complexes connected with a network of ducts which lead either directly to flue gas generation points in the case of sweating operations, or to hoods mounted over intermittent emission points, i.e., directly above a pot furnace or at the point where retorts or muffle furnaces are "broken." Baghouses, ductwork, and air flows (including dilution air required to reduce air temperatures) are designed to accommodate loads from individual and combined sources on a scheduled basis. The overall system is accordingly underdesigned from the standpoint of control of all intermittent sources simultaneously. This approach, taken to reduce costs, is effective to the extent that intermittent sources are scheduled to prevent overloads, and system effectiveness is a function of operator attention to damper positioning. The principal concern expressed by regulatory personnel relates to control system management, i.e., scheduling and damper positioning. Another factor which is important in control system effectiveness is management of the bags and baghouses, i.e., replacement of bags and bag shakedown. If these operational and maintenance factors are properly taken care of then the pollution control system is capable of good performance.

Very limited use of electrostatic precipitators apparently persists because of investments in precipitators, as the ESP has a narrow range of effectiveness for control of zinc oxide. One plant surveyed expressed satisfaction with ESP performance for control of emissions from zinc alloying pot furnaces plus brass and bronze operations, but only after a considerable period required to learn how to operate and maintain the system. The associated regulatory agency admitted satisfaction with performance, but the engineer was quite positive in his conviction that precipitators should not be used in zinc operations.

Baghouse control system efficiencies listed in the NEDS printouts ranged from 95 to 99 percent, with 98 to 99 percent being usual. The measured efficiency for an afterburner baghouse system for a rotary furnace was 99.24 percent (loading to afterburner: 53 kg/hur (117 lb/hr); baghouse effluent load, 0.4 kg/hr (0.88 lb/hr), 0.011 g/scm (0.005 gr/scf).

Air flows to baghouses ranges from 2.8 standard cubic meters per minute (100 scfm) to 850 standard cubic meters per minute (30,000 scfm), with temperatures ranging from about 340 to 450K (160 to 350°F). Since most of the emissions points exhibit air temperatures of 800 to 1400K (1,000 to 2,000°F), dilution is required to lower temperatures to the baghouses.

In addition to the controlled emission points, certain fugitive emission sources exist within an operating plant. These include emissions from product (Zn dust, Zn oxide) conveying systems, and dusts from handling scrap and residues. These sources are generally not controlled except to the extent that airborne matter is swept into the ventilating system associated with baghouse operations. Estimated emissions range from 0.2 kg/1,000 kg (0.2 ton/1,000 tons) processed for screening systems to 2 tons/1,000 tons processed for dust conveyors. Emissions from such sources have not been included in estimates of particulate emissions nationally or from individual plants. Uncontrolled emissions from such sources have the potential to approximately equal the emissions estimated from controlled sources. Such a conclusion must be qualified, however, by the essentially complete lack of documented data on fugitive sources.

6.1.1 Retort Emissions Control Systems

Flue gases from indirect heating are vented without control during most of the cycle. When the furnace is broken for removal of product and ash, and recharging, a hooding system captures emissions which are directed to a baghouse.

6.1.2 Muffle Furnace Emissions Control

Emissions control for muffle furnace is similar to that for retorts, i.e., intermittent emissions from charging operations and during furnace breakdown are swept into a hood/ductwork system and to a baghouse.

In addition, that fraction of the distilled zinc burned to zinc oxide is directed to a product baghouse system.

6.1.3 Emissions Control From Sweating Operations

Sweat furnaces may be completely independent of other operations, including being the only zinc-based operation in a plant. Alternatively, sweating may be integrated directly with operation of a muffle furnace. In all cases, emission control consists of directing the gases which have been in contact with furnace charge, to a baghouse. The flue gases may come from natural gas used solely to provide sweat furnace heat, or may come in part from the hot flue gases of an associated muffle furnace. If the charge is sufficiently "dirty," an afterburner may, or should be, interposed between the furnace and the baghouse. The afterburner approximately doubles fuel requirements. The emissions control system accordingly consists of baghouses plus afterburners. As indicated earlier, the control of such a system has been documented at 99+ percent.

6.1.4 Control of Fugitive Emissions

Specific control of fugitives from general plant operations is not practiced, within the context of providing collection and filtering of the emissions. Control consists of adoption of handling practices to minimize dust formation, for example blanketing hot ash with cold ash.

6.2 ALTERNATIVE CONTROL TECHNIQUES

The baghouse system is the method of preference for the industry, from the standpoint of cost, efficiency, and the built in feature of capturing particulate matter for sale or recycle.

Within the framework of the baghouse system, alternates for consideration in development of New Source Performance Standards consist of possible extension of controls to fugitive sources not presently taken care of; more universal usage of afterburners in sweating operations, and evaluation of possibilities for reduced dust emissions from general plant operations.

Consideration can be given as well to development of uniform standards for designing baghouse systems to reduce sensitivity to operator neglect. Automated damper control is, in principle, an option, but one which plant personnel view as costly and beyond the present state of the art in commercially demonstrated systems. Added baghouse capacity is a further option, desirable, in principle, from the standpoint of providing a better capability to handle overload or emergency situations; this option would, however, add significantly to the cost of pollution control, without necessarily decreasing the complexity of managing and scheduling system operation.

Sulfur oxide and nitrogen oxide emissions are not a control problem within the framework of present standards with natural gas as the fuel. Only in the event that new sources are required to use other fuels should NSPS be necessary for these air pollutants.

6.3 BEST SYSTEMS OF EMISSION REDUCTION

Since essentially all the plants surveyed use the same basic system for particulate control, it is difficult to identify any one plant or system as "best." The principal difference between plants appears to consist of differences in management and operation of systems rather than in basic design features. The "best" system accordingly consists of a properly designed and well operated baghouse system, complemented by afterburners to minimize the load of particulates and unburned hydrocarbons to the baghouse.

Pacific Smelting, in Torrance, California, was selected as a plant which exemplifies a majority of the operations which can be used in secondary zinc plants, controls pollutants with an established complex of baghouses and accessories, and which employs after burners. This plant site was visited during the survey. The plant is equipped with 14 retort furnaces, four muffle furnaces, a rotary kiln sweat furnace, and other sweat furnaces which either operate independently or integrated with muffle furnaces.

The pollution control and product collection (zinc oxide) baghouse complex has 21 baghouses sized from 2.8 standard cubic meters per minute (100 scfm) to 850 standard cubic meters per minute (30,000 scfm). Since the plant is in the metropolitan Los Angeles area and is now surrounded by urban development, its control of air pollution is observed closely by the area pollution control authority. Limited emissions data are available; the measurements of uncontrolled and controlled particulates for a rotary sweat furnace described earlier, i.e., afterburner inlet-53 kg/hr (117 lb/hr); baghouse outlet-0.4 kg/hr (0.88 lb/hr), 0.011 g/scm (0.005 gr/scf); overall efficiency-99.24 percent, were obtained at the Pacific Smelting site.

The Pacific Smelting plant is our present recommendation for testing in the event that New Source Performance Standards are promulgated, since it has a well rounded complement of sources which would need to be tested, and has in place pollution control equipment which represents the current best state of the art. Final selection of a plant for testing might depend, however, on results of costs for testing, since the plant is not well set up for emissions testing.

7.0 EMISSION DATA

7.1 AVAILABILITY OF DATA

Emissions data obtained from state and local agencies and the National Environmental Data System are summarized in Table 7-1. Data recorded in NEDS were primarily based on engineering judgment. Limited data from actual emissions tests were obtained. These data generally support emissions factors used in the study, and in addition corroborate effectiveness of emissions control systems.

7.2 METHOD FOR SAMPLE COLLECTION

EPA Method 5 is the applicable standard method for sample collection and analysis of particulates from the secondary zinc industry. Information on specific methods for emission testing was not obtained in the survey.

Methods for collection and analysis of particulates from fugitive sources require further development.

TABLE 7.1. EMISSIONS INFORMATION

Company		Process operation	Control equipment	Pollutants
		A. NEDS		
Pacific Smelting	1978	Retorts	FF	Particulates
		Muffle furnaces	FF	NO_x
		Rotary sweat furnaces	FF	HC
		Reverberatory/kettle sweat furnaces	FF	
		Dust condensers	FF	
		Screening equipment	None	
W. J. Bullock	1977	Kettle sweat	FF	Particulates
Aetna Metals	1977	Reverberatory sweat	FF	Particulates, NO_x
		Alloy furnace	NC	Particulates, NO_x, HC, CO
		Muffle furnace	FF	Particulates, SO_x, NO_x, HC, CO
Apex Smelting[a/]	1974	Reverberatory sweat furnace	NC	Particulates, NO_x
Hugo Neu Proler[a/]	1977	Retorts	FF	Particulates, NO_x
		Sweat furnace	FF	Particulates, NO_x
Inland Metals[a/]	1973	Reverberatory furnace	FF	Particulates
S-G Metals	1978	Pot furnace	ESP	Particulates
Canton Metal Alloys	1975	Sweat furnace	NC	Particulates
Federated Metals	1977	Retorts	FF	Particulates, NO_x, HC, CO
Superior Zinc	1976	Calcining kiln	Wet scrubber	Particulates, SO_x, NO_x
		Retorts[a/]	FF	Particulates
Gulf Reduction Corporation	1970	Retorts	NC	Particulates, NO_x
		B. California - Air Quality Unit		
Pacific Smelting		Rotary furnace	FF Afterburner	Particulates, CO NO_x
		Muffle furnace	FF	Particulates
		Retorts	FF	Particulates
Aetna Metals		Sweat furnace	FF Afterburner	Particulates Organic acids

a/ Ceased zinc operations

8.0 STATE AND LOCAL EMISSION REGULATIONS

State and local emission regulations that apply to new sources in the secondary zinc smelting and refining industry are summarized in this section. Eleven of the 13 states which have plants of this industry (Table 4-1) were examined. It is believed that the 11 states are representative of all areas where secondary zinc plants are likely to be built. These regulations were taken primarily from the Environment Reporter with supplemental information from contacts with state air pollution control agencies.

The emission regulations are summarized in Table 8-1. The allowable emissions in each state are compared for a hypothetical plant, considered typical of a new plant which might be built. The annual design capacity for distillation is 19,900 metric tons (21,900 short tons). The model plant has one reverberatory furnace, one rotary furnace, 10 retort furnaces, and three muffle furnaces. Each furnace was treated as a source. The parameters of the furnaces are listed in Table 8-2. The plant emissions are collected in a baghouse and vented through 80, 20 cm (8-in.) diameter pipes at 6 meters (20 ft) above ground. This is considered equivalent to a 6 meter (20 ft) stack with a 1.8 meter (6 ft) inside diameter. The distillation furnaces are heated indirectly. The exhaust stream from the distillation process is separate from the combustion exhaust stream. The process chambers of the distillation furnaces are enclosed, except for some small vents, during most of the processing time. Emission controls are applied only when the furnaces are "broken" or opened to insert or remove material. Plant operations are scheduled to avoid breaking a large number of distillation furnaces at a time, a practice which reduces the required emission control capacity. In the model plant the flow through the baghouse under normal operating procedures is 2,000 m^3/min (71,000 acfm) at a temperature of 380K (684°R). The stack exit velocity under these conditions is 13 meters/sec (43 ft/sec). Part of the year the plant will be operating below the normal rate as furnaces are out of service for maintenance. The annual average flow, based on the operating hours for each source in Table 8-1 is 1,687 m^3/min (59,587 acfm).

Table 8-3 summarizes the particulate emissions regulations of the 11 states as applied to the whole plant. It is based on Table 8-1, with the plant operating under normal conditions.

The calculations for Table 8-3 (except Texas) were made by first finding the total emissions of the model plant if each source emits what the state allows (Table 8-1) for the number of hours the source operates in the year (Table 8-2). The allowable emissions per hour for the plant under average operating conditions were the annual emissions divided by (24 x 365) hours per year. The allowable emissions per hour under normal operating conditions (listed in

TABLE 8-1. SUMMARY OF PARTICULATE EMISSIONS REGUALTIONS FOR NEW SECONDARY ZINC PLANTS

State	Visible emissions percent opacity	General process regulation[b]	Date of last revision	Allowable particulate emission for each furnace							
				Reverberatory furnace		Rotary furnace		Retort furnace		Muffle furnace	
				kg/hr	lb/hr	kg/hr	lb/hr	kg/hr	lb/hr	kg/hr	lb/hr
Alabama	20	$E = 3.59\ P^{0.62}$ if $P < 30$	9/76	2.7	5.9	3.2	7.1	0.4	1.0	1.2	2.7
California[a]	20	Lesser of concentration limit from Table 404(a) and emission rate limit from Table 405(a)	10/5/79	1.1	2.5	3.0	6.6	0.5	1.0	1.3	2.9
Illinois	30	$E = 2.54\ P^{0.534}$ if $P < 450$	5/3/79	1.8	3.9	2.1	4.6	0.4	0.8	0.9	2.0
Kansas	20	$E = 4.1\ P^{0.67}$ if $P \leq 30$	1/1/74	3.2	7.1	3.9	8.6	0.5	1.0	1.4	3.0
Massachusetts	20	Emission rate limit from Table 6 if $P \leq 30$	1/1/78	1.4	3.2	1.7	3.7	0.2	0.5	0.7	1.6
New Jersey	20	0.5 lb/hr for small sources;[c] 0.02 gr/scf, but not to require collection efficiency > 99%	3/18/77	0.2	0.5	1.6	3.5	0.2	0.5	0.5	1.0
New York	20	A: 99% cleaning or BACT[d] B: 90-91% cleaning C: 70-75% cleaning D: No cleaning required	8/23/79	0.1 0.8 2.5 -	0.2 1.9 5.6 -	0.3 2.4 6.8 -	0.6 5.4 15.0 -	0.02 g g -	0.05 g g -	0.1 0.9 2.6 -	0.2 2.0 5.6 -
Ohio	20	$E = 4.10\ P^{0.67}$ if $P \leq 30$ or sliding scale cleaning efficiency[e]	9/25/78	1.7	3.7	3.7	8.1	0.5	1.0	1.4	3.0
Oklahoma	20	$E = 4.10\ P^{0.67}$ if $P \leq 30$	4/15/71	3.2	7.1	3.9	8.6	0.5	1.0	1.4	3.0
Pennsylvania	20	Less stringent of 0.03 gr/dscf or $A = 0.76\ (FW)^{0.42}$	4/9/79	0.2	0.3	1.6	3.5	0.2	0.5	0.5	1.0
Texas	20	$E = 0.048\ q^{0.62}$[f]	5/7/79	-	-	-	-	-	-	-	-

[a] South Coast Air Quality Management District.

[b] E = Allowable emissions (lb/hr).
P = Process weight rate (tons/hr)
A = Allowable concentration of emissions (grains per dry standard cubic foot).
F = 0.01 for sweating operations.
F = 0.3 for refining (distilling) operations.
W = Production rate (tons/hr).
q = Stack effluent flow rate (acfm).
Tables 404(a), 405(a), and 6 are tables in the appropriate state regulations.

[c] A small source is one with uncontrolled emissions less than or equal to 50 lb/hr and with a gas effluent rate less than or equal to 3,000 scfm.

[d] The environmental rating A, B, C, or D is assigned on the basis of the nature of the emissions, the location of the plant, the dispersion of the emissions, and the preexisting air quality situation. For the environmental ratings B and C, the required cleaning efficiency depends on the uncontrolled emission rate.

[e] Ohio has an emissions limit based on process weight rate and a cleaning efficiency limit with a sliding scale. The more stringent limit applies.

[f] The Texas standard applies to the entire plant, not to the individual sources. There is a correction factor if the effective stack height is less than the standard effective stack height, but this correction factor does not apply to the model plant, which has an effective stack height of 33 meters (73 ft) and a standard effective stack height of 24 meters (52 ft). Texas also has a limit on net ground level particulate concentration.

[g] For a small source (uncontrolled emission rate less than or equal to 10 lb/hr) with an environmental rating of B or C, the required cleaning efficiency will be specified by the commissioner.

TABLE 8-2. MODEL SECONDARY ZINC PLANT PARAMETERS

	Units	Reverberatory furnace	Rotary furnace	Retort furnace	Muffle furnace
Type of process		Sweat	Sweat	Distillation	Distillation
Number of furnaces		1	1	10	3
Operating rate	hr/yr	5,000	5,000	6,000	6,500
Production	MT/yr	4,500	6,800	540	2,950
	Short tons/yr	5,000	7,500	600	3,250
Process weight rate	kg/hr	2,000	2,700	110	570
	lb/hr	4,500	6,000	250	1,250
Uncontrolled particulate	kg/hr	8.5	27	2.1	10.2
emissions rate	lb/hr	18.7	60	4.7	22.5
Gas emission rate	m^3/min	76	864	105	195
	ft^3/min	2,700	30,500	3,700	6,900
	scfm	2,000	20,600	3,000	5,900
Gas emission temperature	K	394	436	367	346
	°R	710	785	660	622

TABLE 8-3. PARTICULATE EMISSION REGULATIONS FOR THE WHOLE MODEL PLANT

State	Allowable particulate emissions kg/hr	lb/hr
Alabama	10.9	24.0
California	9.9	21.9
Illinois	7.9	17.5
Kansas	12.1	26.7
Massachusetts	5.9	13.0
New Jersey	4.3	9.4
New York[a] A	0.7	1.5
B	6.4	14.0
C	18.2	40.2
D	-	-
Ohio	10.9	24.0
Oklahoma	12.1	26.7
Pennsylvania	4.2	9.3
Texas	22.2	48.9

[a] See footnotes d and g to Table 8-1. For Table 8-3 retort furnaces are assumed to have a 90% cleaning requirement for environmental rating B and a 70% cleaning requirement for environmental rating C.

Table 8-3) are the average hourly allowable emissions times the factor 1.1855 = 2,000 ÷ 1,687, the ratio of the normal flow rate to the average flow rate.

The major pollutant emitted by the secondary zinc industry is particulate matter, mainly zinc oxide. The emissions are collected by fabric filters. Often the zinc content of the material collected on the filter is sufficient to permit recycling or sale for agricultural use. A rotary furnace is often equipped with an afterburner, which is used if the scrap charge contains a significant quantity of combustible contaminants. The energy consumption of the afterburner, when it is in use, nearly equals the process energy consumption in the rotary furnace.[2]

Although the sweat furnaces are heated directly, the distillation furnaces are heated indirectly. Since natural gas with standby fuel oil is the usual fuel, the combustion exhaust is not a major source of pollutants and no emissions controls are placed on it in current practice.

The flow of gasses from the furnaces to the baghouse is controlled by a complex set of ducts and dampers. The control efficiency depends to a great extent on operating practices: how carefully the dampers are adjusted, whether leaks are permitted in the fabric filters, how often the filters are cleaned, and how many furnaces are broken at a time.

Seven of the 11 states have particulate emission limits based on process weight rate. Two of them, Ohio and California's South Coast Air Quality Management District also have another standard. California's other standard is a concentration limit with a sliding scale based on the volume of gas discharged. The more stringent of the two applies. Ohio's other standard is based on control efficiency with a sliding scale. Again the more stringent of the two applies. In Ohio, the cleaning efficiency standard applied to the model plant's sweat furnaces and the process weight standard applied to the distillation furnaces, because the sweat furnaces operate at a lower temperature and have a lower uncontrolled emissions factor (ratio of emissions to process weight) than the distillation furnaces.

Pennsylvania has a limit based on production rate and a concentration limit of 0.046 g/dscm (0.02 gr/dscf), with the less stringent of the two applying. New Jersey has a concentration limit of 0.046 g/dscm (0.02 gr/dscf) and a collection efficiency requirement of 99 percent with the less stringent of the two applying. In both states the 0.046 g/dscm (0.02 gr/dscf) concentration limit was less stringent for each source. New Jersey, however, does not require a small source (Table 8-1, footnote c) to reduce emissions below 0.23 kg/hr (0.5 lb/hr). New York's regulation is based on efficiency of control with a sliding scale (Table 8-1, footnotes d and g). Texas has an emission rate limit based on the stack effluent flow rate with a correction factor based on stack exit velocity, gas exit temperature, stack height, and the inside diameter of the stack opening. The correction factor was 1.0 for the model plant. Texas also limits the net ground level concentration of particulates at the property line (Table 8-1, footnote f).

The most stringent particulate emission limit is the 99 percent cleaning required by New York if the environmental rating is A. The most stringent limit applicable to a whole state is that of Pennsylvania. The applicable limit is 0.046 g/dscm (0.02 gr/dscf). This requires 90 to 98 percent cleaning efficiency for the various sources in the model plant.

Using the information on state regulations a Model IV calculation[3] was made to estimate the impact of new source performance standards in 1984 and 1989. The new source performance standard was assumed to be 0.046 g/dscm (0.02 gr/dscf), which equals the standard of the most stringent state. The emissions under state regulation were assumed to equal the state emission limits. The calculation was done for each of the 11 states and the results were added. Since (Table 4-1) the production capacities of most of the states is not known, an allocation was necessary.

The allocation of the midpoint (92,000 Mg (101,000 tons)) of the range of estimates of national production capacity to the 16 plants was performed as follows. The known capacities were assigned to their respective plants. The three alloying plants were each assigned 300 Mg (330 tons)based on the information in Table 4-1 for the plant in Kansas. The plant in Oklahoma was assigned 11,100 Mg (12,200 tons) since it has 14 retorts and 91 kg/hr (0.1 short tons/hr) is considered a typical retort capacity. The New Jersey plant was assumed to be similar to the Oklahoma plant. Huron Valley Steel and Superior Zinc were assigned 10,000 and 6,000 Mg (11,000 and 7,000 tons), respectively, by rounding

the lower bound (Table 4-1) upwards to the next 1,000 Mg (1,100 tons). The capacity which was still unallocated was divided equally among the remaining four plants, which assigned each of them 4,700 Mg (5,200 tons).

The resulting allocation of capacities to states was used in the Model IV calculation. The 11 states which were reviewed represent 84 percent of the allocated national capacity. The estimated national impact of new source performance standards is the 11-state impact divided by 0.84.

The fractional utilization of existing capacity was assumed to be 0.75 for each state. The national average in 1979 is believed to be 0.5 to 0.6, but 0.75 is believed to be more typical of recent years.

If the projection of future production (Figure 4-4) is realized and if capacity is expanded so that production does not exceed 90 percent of capacity, then the 1989 capacity would be 102,000 Mg (112,000 tons). If the 1979 capacity is 92,000 Mg (101,000 tons), this would require an average compound annual growth in capacity of 1.0 percent.

The construction and modification rate to replace obsolete capacity was assumed to be 0.018 as a decimal fraction of baseline year capacity. This assumption was based on the following assumptions. The rate (13 plants in 22 years) of replacing present capacity with new capacity will continue (Section 4.2.4). This pattern of entry and exit involves the smaller plants: the average entrant will have a capacity equal to one-half the average capacity of the industry.

The results of the Model IV calculation are an estimated national impact of 19 Mg (21 tons) per year in 1984 and 39 Mg (43 tons) per year in 1989. In 1984 allowable emissions under State Implementation Plans would be 250 Mg (275 tons) while under New Source Performance Standards they wold be 231 Mg (255 tons). In 1989 allowable emissions under State Implementation Plans would be 273 Mg (289 tons) while under New Source Performance Standards they would be 224 Mg (246 tons). In 1979 the allowable emissions under the State Implementation Plans are 238 Mg (262 tons) per year. The actual impact may be much less than this because Model IV assumes that a plant will emit all the pollutants which the applicable regulations allow. There is reason to believe that secondary zinc plants are emitting less than the present state regulations allow. One major plant is emitting approximately 10 percent of its allowable emissions.[4] The particulates which are collected by the fabric filters have economic value: they can usually be recycled or sold. Thus there is an economic incentive to exceed present state requirements. Only 1 plant which was contacted stated that they are not selling or reprocessing the material which their air pollution control system collects.

It appeared to project personnel that state enforcement activities are focused primarily on visible emissions. Only when the visible emissions standard (usually 20 percent opacity with exceptions for short intervals) is repeatedly violated are measurements taken to ascertain compliance with process weight standards, cleaning efficiency standards, or particulate concentration standards.

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